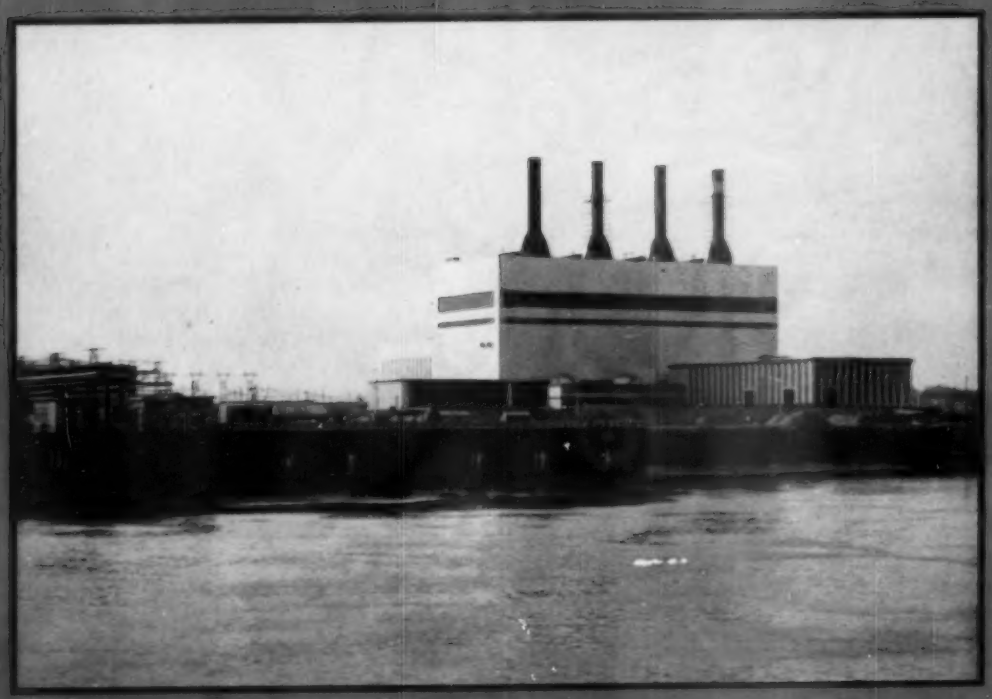
COMBUSTION

DEVOTED TO THE ADVANCEMENT OF STEAM PLANT DESIGN AND OPERATION

October 1955



View of the Nantes-Cheviré Power Station of the Electricité de France (Story on page 47)

Integrated Steam Station Protection

Welding Technique Permits Ultrasonic Testing of Piping

Accuracy of Sampling Mixed Coals

Formation of Bonded Deposits

Launching view of the Seawolf, America's second nuclear-powered submarine, for which Combustion built the reactor vessel and other components of the nuclear power system.

Combustion Engineering, *Builder of Nuclear Components for Seawolf,* becomes Third Major AEC Contractor to enter Naval Reactor Development Program

On August 11, the Atomic Energy Commission announced the award of a contract to Combustion Engineering for the design, manufacture, assembly and test of a submarine nuclear power reactor and its related equipment. Only two companies had previously been awarded such contracts—the Westinghouse Electric Corporation and General Electric Company.

Combustion brings to this important assignment the experience already gained in building the reactor vessel and other related components for both the Seawolf and its prototype in the sphere at West Milton, N. Y., which recently became the first nuclear source of commercially distributed electricity for public use. This experience is further augmented by design, research and development work in the field of atomic power over the past eight years, including the manufacture of the reactor vessel, presently in process, for the AEC-Duquesne Light plant —the country's first commercial-size nuclear power station.

In executing its AEC submarine contract, Combustion will utilize new manufacturing facilities now being erected at its Chattanooga plant, plus additional facilities to be established in a new Nuclear Engineering and Development Center scheduled for completion in 1956. *Thus Combustion Engineering will become the first company in the country to provide its own facilities for the construction of a naval nuclear reactor.*

COMBUSTION ENGINEERING

Combustion Engineering Building
200 Madison Avenue, New York 16, N. Y.

C-E

8-865

STEAM GENERATING UNITS; NUCLEAR REACTORS; PAPER MILL EQUIPMENT; PULVERIZERS; FLASH DRYING SYSTEMS; PRESSURE VESSELS; DOMESTIC WATER HEATERS; SOIL PIPE

COMBUSTION

DEVOTED TO THE ADVANCEMENT OF STEAM PLANT DESIGN AND OPERATION

Vol. 27 **No. 4**

October 1955

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EPA

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THIS cowboy thought he could ride anything—until he was thrown by a Brahman bull, a critter no more discomforting than many a critical piping job. For such, our prefabricating facilities and installing experience both assure you that Mitchell will master your toughest problem from start to finish, saving you time and money. Send us your specifications.

W. K. MITCHELL & CO., INC.

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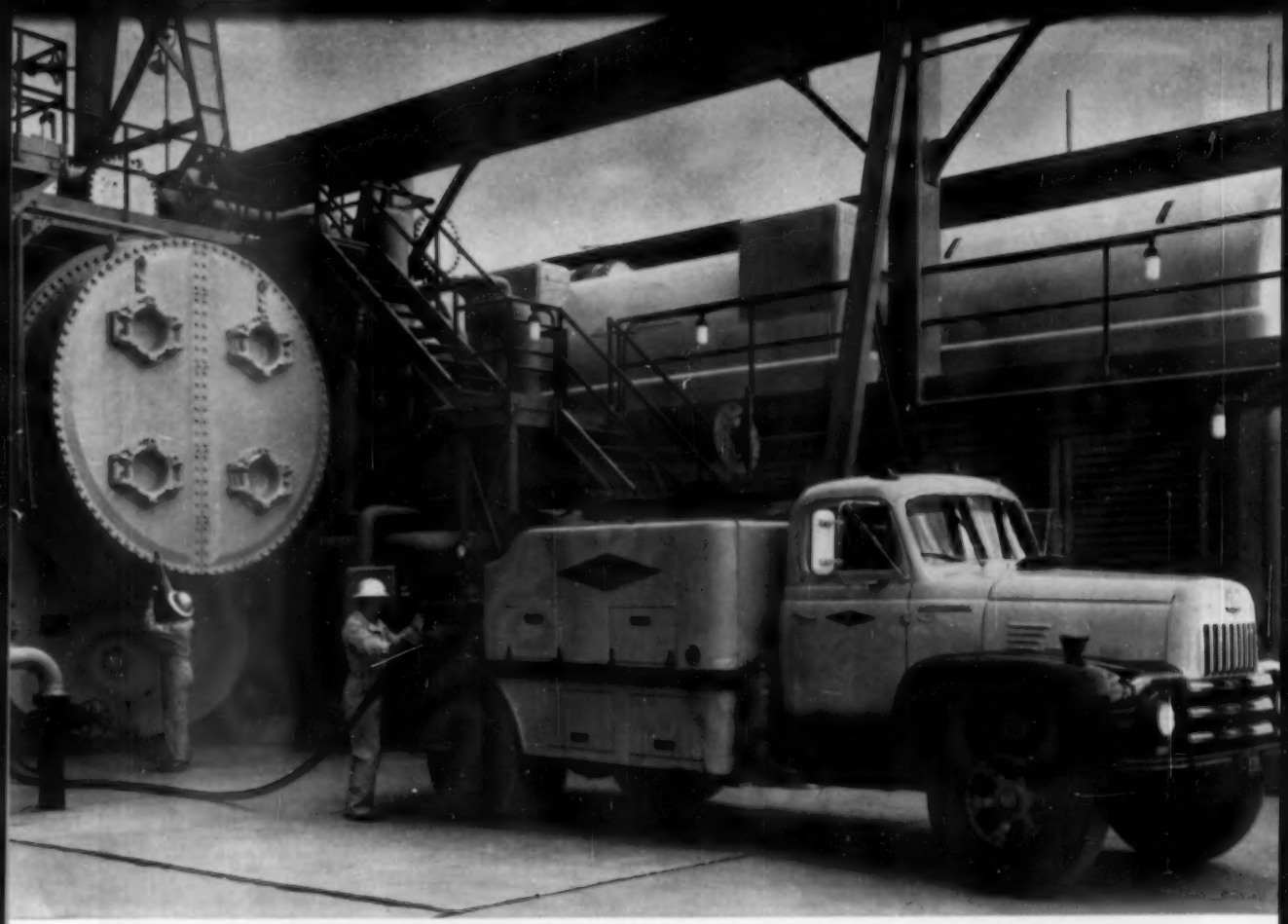
PIPING FABRICATORS AND CONTRACTORS



CONDENSER VACUUM INCREASED 1.7 INCHES IN 13 HOURS

DOWELL chemical cleaning boosted heat transfer efficiency 25 per cent

An iron oxide scale $\frac{1}{16}$ of an inch thick had seriously cut the efficiency of a surface condenser in this company's power plant. When the operator decided it was necessary to remove the deposits *fast*, he called Dowell.

Dowell engineers took especially prepared solvents to the plant in truck-mounted tanks. They applied the chemicals through regular connections using Dowell-designed equipment, which includes all necessary pumps and control devices. Both the steam and water sides of the condenser were cleaned in just 13 hours.

As a result of Dowell Service, the condenser's heat-transfer efficiency was increased 25%; vacuum was boosted from 25.90 inches to 27.60 inches. The operator reported that the increased operating efficiency of the condenser paid for the chemical cleaning within 10 days.

Dowell holds dismantling of equipment to a minimum on every job. The liquid solvents used can go wherever steam or water will flow, reaching places inaccessible to other cleaning methods. Dowell's experience, especially designed equipment and job-tailored solvents are designed to restore maximum efficiency to your equipment—fast!

For full information and estimates on cleaning *your* production facilities, call the nearest Dowell office. Or write Dowell Incorporated, Dept. J25, Tulsa 1, Oklahoma.

chemical cleaning service for industry

DOWELL

A SERVICE SUBSIDIARY OF THE DOW CHEMICAL COMPANY

Ljungstrom field engineers assure you of maximum return on your preheater investment

Your Air Preheater Corporation field engineer aims to visit your installation at least once a year. It's his job to give you the help and advice you need to assure you of maximum return on your Ljungstrom Air Preheater investment.

This field service is another factor in making the Ljungstrom the most economical heating surface on the modern boiler. And it helps explain why 7 out of 10 modern preheater installations are Ljungstroms.

Get all the details on the Ljungstrom Air Preheater. Why it cuts fuel costs . . . helps maintain higher boiler efficiencies . . . why it speeds cleaning and maintenance. You'll find all the details in the new, 38-page reference manual, "Ljungstrom Air Preheaters." Write for your free copy, today!

Advantages of the Ljungstrom Air Preheater

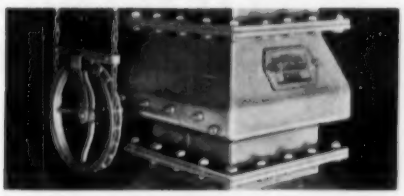
- Size for size, recovers more heat than any other type.
- Reduces fuel consumption. Permits use of lower-grade fuels. Increases boiler output and reliability.
- Eliminates cold spots . . . keeps corrosion to a minimum.
- Easier, faster to clean and maintain.
- Requires far less supporting steel and is quickly erected.

The Air Preheater Corporation 60 East 42nd Street, New York 17, N. Y.

Any way you look at it . . .

you get more value when you

buy the New S·E·CO. Coal Valve



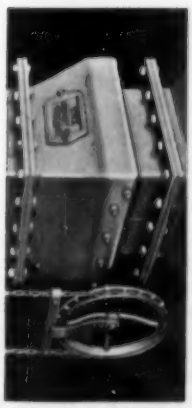
Any way you look at it the new S-E-Co. Coal Valve gives you more value . . . more life expectancy . . . more dependability . . . more ease of operation.

More life because of its heavy construction. The body is made of ⅜" thick steel with ¾" thick flanges. More life because stainless steel is used to combat corrosion — as gate liner, for pinions, gate rollers and grease seal retainers.

More dependability of operation due to the unique ladder racks and multiple faced pinions, both of which are self-cleaning so that tooth engagement is sure. More dependability since two racks are used, one on each side of gate, located far above normal coal flow, to assure straight line gate movement without jamming or binding.

More ease of operation due to large gate supporting rollers equipped with ball bearings and grease seals for pressure lubrication from outside the valve body.

The best costs little more than the average. A S-E-Co. representative would be happy to talk it over with you.



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BUNKER TO STOKER EQUIPMENT

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Fresh, Clean Ink for a Year of Trouble-free Recording

★ You won't have any messy, time-consuming re-inking of pens on the new Bailey Recorders. The entire system is white-glove clean—hermetically sealed, non-evaporating, non-corrosive. Gone is any chance of sludge or oxide formation. Gone are clogged pens, interrupted records, unsightly splashes.

The transparent plastic ink sacs are changed once a year—that's all. Capillary tubing carries fresh, clean ink to the pens continuously without any day-to-day attention.

This exclusive new inking system* is only one of the many time-saving, money-saving distinctive features of the new Bailey Recorder.

Ask for Product Specification E12-5. P34-1

*Now available for the New Bailey Recorder only.

ONLY BAILEY OFFERS ALL THESE ADVANTAGES IN A SINGLE RECORDER

- Pre-calibrated plug-in receiver units
- Up to four pneumatic or electronic receivers —or two receivers and two integrators
- Any four variables on one chart—easily read and interpreted
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- Faster ordering—from stock
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Controls for Power and Process

BAILEY METER
Controls for
TEMPERATURE
PRESSURE
GAS ANALYSIS
FLOW · LEVEL
RATIO · DENSITY

This new soot blower packing outlasts every type I've tried!
That's J-M CUMPAC 236- it's specially designed to withstand high temperatures and pressures

Now available at your local Johns-Manville Packing Distributor

saves time and trouble . . . reduces expensive soot blower repacking

YOU MAY HAVE ALREADY discovered that traditional soot blower packings cannot withstand the higher temperatures and pressures employed in boiler operation today. Now, Johns-Manville brings you a new packing specially developed for this service. Cumpac 236 won't harden or vulcanize and greatly outlasts all other packings of the conventional types.

In plants where it has already been introduced, users report excellent results. Soot blower repacking has been reduced to a substantial degree.

How it is constructed: Cumpac 236 resists high temperatures and pressures because it is specially made of high purity asbestos yarn braided over a plastic core of special heat-resistant composition and lubricated with mica.

This material is formed into a combination of lip type and solid packing which provides low friction contact with the soot blower tube and seals the entire stuffing box.

Your J-M Packing Distributor carries No. 236 Cumpac sets for all popular soot blowers. He also stocks other Johns-Manville Packings and Gaskets. Ask him for the Cumpac 236 folder, PK-100A, or write Johns-Manville, Box 60, N. Y. 16, N. Y. In Canada, Port Credit, Ontario.

JOHNS-MANVILLE PRODUCTS

Johns-Manville PACKINGS & GASKETS

C-E POSTWAR

Station	Company	Units	Kilowatts*
1945-47			
PORT WASHINGTON	Wisconsin Electric Power Co.	1	80,000
EDGAR	Boston Edison Co.	1	80,000
PORT WASHINGTON	Wisconsin Electric Power Co.	1	80,000
1948			
DUNKIRK	Niagara Mohawk Power Co.	2	200,000
TITUS	Metropolitan Edison Co.	2	150,000
O. H. HUTCHINGS	Dayton Power & Light Co.	2	132,000
RUSSELL	Rochester Gas & Electric Co.	1	62,500
PORT WASHINGTON	Wisconsin Electric Power Co.	1	80,000
LEE	Duke Power Co.	2	200,000
EDGAR	Boston Edison Co.	1	80,000
1949			
GOUDEY	N. Y. State Electric & Gas Corp.	1	75,000
SEWAREN	Public Service Elec. & Gas Co.	1	125,000
MERAMEC	Union Electric Co. of Missouri	1	125,000
DANSKAMMER	Central Hudson Gas & Elec. Corp.	1	65,000
BECKJORD	Cincinnati Gas & Electric Co.	1	100,000
1950			
HUTSONVILLE	Central Illinois Public Service	1	75,000
RIVERBEND	Duke Power Co.	2	220,000
ALBANY	Niagara Mohawk Power Corp.	3	300,000
GOLDSBORO	Carolina Power & Light Co.	1	75,000
GLENWOOD	Long Island Lighting Co.	1	100,000
CHESTERFIELD	Virginia Electric & Power Co.	1	100,000
HENNEPIN	Illinois Power Co.	1	75,000
LUMBERTON	Carolina Power & Light Co.	1	75,000
CUTLER	Florida Power & Light Co.	1	75,000
O. H. HUTCHINGS	Dayton Power & Light Co.	2	132,000
BUCK	Duke Power Co.	2	250,000
RUSSELL	Rochester Gas & Electric Co.	1	62,500
OAK CREEK	Wisconsin Electric Power Co.	1	120,000
HAWTHORN	Kansas City Power & Light Co.	1	100,000
TITUS	Metropolitan Edison Co.	1	75,000
URQUHART	So. Carolina Generating Co.	1	75,000
ETIWANDA	Southern California Edison Co.	2	250,000
FAR ROCKAWAY	Long Island Lighting Co.	1	100,000
DANSKAMMER	Central Hudson Gas & Elec. Co.	1	66,000
EASTLAKE	Cleveland Elec. Illuminating Co.	3	375,000
KEARNY	Public Service Elec. & Gas Co.	2	290,000
CONTRA COSTA	Pacific Gas & Electric Co.	2	200,000
CROMBY	Philadelphia Electric Co.	1	200,000
BECKJORD	Cincinnati Gas & Electric Co.	1	100,000
OAK CREEK	Wisconsin Electric Power Co.	1	120,000
MONTVILLE	Connecticut Light & Power Co.	1	75,000
EDGE MOOR	Delaware Power & Light Co.	1	75,000
NELSON	Gulf States Utilities Co.	1	100,000
WOOD RIVER	Illinois Power Co.	1	100,000
GREENIDGE	N. Y. State Electric & Gas Corp.	1	100,000
URQUHART	So. Carolina Generating Co.	1	75,000
PIACENZA	Societa Edison	2	125,000
TAVAZZANO	Societa Termo Electtrica Italiana	2	125,000
1951			
JOPPA	Electric Energy, Inc.	4	624,000
PORTSMOUTH	Virginia Electric & Power Co.	1	100,000
HUTSONVILLE	Central Illinois Public Service	1	75,000
MERAMEC	Union Electric Co. of Missouri	1	125,000
KINGSTON	Tennessee Valley Authority	4	600,000
TOMKINS COVE	Rockland Light & Power Co.	1	62,500
RIVERBEND	Duke Power Co.	2	270,000
BARRY	Alabama Power Co.	2	250,000
EASTLAKE	Cleveland Elec. Illuminating Co.	1	200,000
EDGAR	Boston Edison Co.	1	80,000
ALBRIGHT	Monongahela Power Co.	1	125,000
WEADOCK	Consumers Power Co.	1	135,000
NORTH OMAHA	Omaha Public Power District	1	75,000
ALBANY	Niagara Mohawk Power Co.	1	100,000
LAWRENCE	Kansas Power & Light Co.	1	50,000
POTOMAC RIVER	Potomac Electric Power Co.	1	100,000
URQUHART	So. Carolina Generating Co.	1	100,000
GLENWOOD	Long Island Lighting Co.	1	100,000

Station	Company	Units	Kilowatts*
1951 (cont'd.)			
SANDOW	Texas Power & Light Co.	3	300,000
COLLIN COUNTY	Texas Power & Light Co.	1	150,000
1952			
PORTSMOUTH	Virginia Electric & Power Co.	1	100,000
KINGSTON	Tennessee Valley Authority	4	800,000
MANRESA ISLAND	Connecticut Light & Power Co.	1	100,000
JOHN SEVIER	Tennessee Valley Authority	2	400,000
VERMILION	Illinois Power Co.	1	75,000
GORGAS	Alabama Power Co.	1	150,000
VERMILION	Illinois Power Co.	1	100,000
POTOMAC RIVER	Potomac Electric Power Co.	1	100,000
MORRO BAY	Pacific Gas & Electric Co.	2	312,000
MILLIKEN	N. Y. State Electric & Gas Corp.	1	125,000
HAWTHORN	Kansas City Power & Light Co.	1	100,000
CUTLER	Florida Power & Light Co.	1	125,000
JOPPA	Electric Energy Inc.	2	312,000
ED. F. BARRETT	Long Island Lighting Co.	1	156,000
GALLATIN	Tennessee Valley Authority	2	500,000
X-3	Southwestern Public Service Co.	1	100,000
1953			
STATE LINE	Chicago Dist. Elec. Gen. Corp.	1	191,000
JOHN SEVIER	Tennessee Valley Authority	1	200,000
B. C. COBB	Consumers Power Co.	1	135,000
DAN RIVER	Duke Power Co.	1	150,000
X-4	Southwestern Public Service Co.	1	100,000
POSSUM POINT	Virginia Electric & Power Co.	1	100,000
RIVER ROUGE	Detroit Edison Co.	1	260,000
WHITE RIVER	Indianapolis Power & Light Co.	1	100,000
CADSBY	Utah Power & Light Co.	1	100,000
SEWARD	Pennsylvania Electric Co.	1	125,000
KINGSTON	Tennessee Valley Authority	1	200,000
CAPE FEAR	Carolina Power & Light Co.	1	125,000
MYSTIC	Boston Edison Co.	1	125,000
OAK CREEK	Wisconsin Electric Power Co.	1	120,000
OCOTILLO	Arizona Public Service Co.	1	100,000
DEAN H. MITCHELL	No. Indiana Public Service Co.	1	125,000
TANAGAWA	Kansai Electric Power Co.	2	150,000
KARITA	Kyushu Electric Power Co.	1	75,000
1954			
B. C. COBB	Consumers Power Co.	1	156,000
CHIBA	Tokyo Electric Power Co.	1	125,000
LIEBERMAN	Southwestern Gas & Elec. Co.	1	100,000
TWIN ISLAND	Erie Mining Co.	2	150,000
YATES	Georgia Power Co.	1	125,000
GULFPORT	Mississippi Power Co.	1	75,000
RUSSELL	Rochester Gas & Electric Co.	1	75,000
EDDYSTONE	Philadelphia Electric Co.	1	325,000
JONES STREET	Omaha Public Power District	1	100,000
PALATKA	Florida Power & Light Co.	1	75,000
MISTERSKY	City of Detroit	1	50,000
1955			
W. SPRINGFIELD	Western Massachusetts Elec. Co.	1	100,000
ALLEN	Duke Power Co.	2	330,000
TECUMSEH	Kansas Power & Light Co.	1	90,000
YORKTOWN	Virginia Electric & Power Co.	1	150,000
HUNTLEY	Niagara Mohawk Power Co.	1	200,000
MONTROSE	Kansas City Power & Light Co.	1	150,000
———	South Carolina Elec. & Gas. Co.	1	125,000
WILL COUNTY	Commonwealth Edison Co.	1	250,000
———	California Electric Power Co.	1	60,000
SCHUYLKILL	Philadelphia Electric Co.	1	175,000
CLARKE	Southern Nevada Power Co.	1	60,000
SAM BERTRON	Houston Light & Power Co.	1	156,000
TAIT	Dayton Power & Light Co.	1	125,000
PORTLAND	Metropolitan Edison Co.	1	165,000
BECKJORD	Cincinnati Gas & Electric Co.	1	156,250
CRAWFORD AVE.	Commonwealth Edison Co.	1	200,000
WEADOCK	Consumers Power Co.	1	150,000
POTOMAC RIVER	Potomac Electric Power Co.	1	100,000
———	Cleveland Elec. Illuminating Co.	1	250,000

*Where more than one unit is indicated, figure represents aggregate capacity.

REHEAT UNITS

In the 10-year period since 1945, when the Wisconsin Electric Power Company ordered the first postwar reheat boiler, the utility industry has ordered

168 C-E REHEAT BOILERS

for a total capacity of more than

20,000,000 KILOWATTS

This is over 25 percent of the total steam-generated capacity of the entire utility industry as of January 1, 1955.

Through August 1955, 108 of these boilers, with an aggregate capacity of nearly 12,000,000 kilowatts, had been placed in service.

Controlled Circulation

The first postwar contract for a C-E Controlled Circulation Boiler was placed in 1950 by Virginia Electric & Power Company for its Chesterfield Station. Through August, 1955, 56 of these boilers, representing a total capacity of 8,500,000 kw, had been ordered.

The preference for controlled circulation has grown steadily in recent years and is particularly manifest in the current year, accounting for more than 70 percent of the capacity ordered through August. This is attributable both to the outstanding service records of C-E Controlled Circulation Boilers and to the trend toward pressures in the 2400-lb range. This pressure range applies to seven of the thirteen controlled circulation boilers ordered thus far in 1955.

Tilting Tangential Burners

Tangential firing with tilting burners has become an almost universally accepted feature of C-E utility boilers. Of the 168 C-E Reheat Units represented by the list opposite, 149 (88 percent) have been or will be fired with C-E Tilting Tangential Burners.

8-869

COMBUSTION ENGINEERING

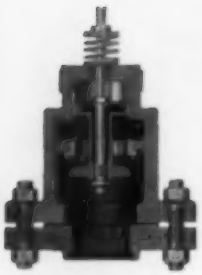
Combustion Engineering Building
200 Madison Avenue, New York 16, N. Y.

STEAM GENERATING UNITS; NUCLEAR REACTORS; PAPER MILL EQUIPMENT; PULVERIZERS; FLASH DRYING SYSTEMS; PRESSURE VESSELS; DOMESTIC WATER HEATERS; SOIL PIPE

C-E

BAYER
STEPS UP BOILER PERFORMANCE

DISTINCTLY DIFFERENT



Bayer Balanced Valves are famous for their long life and continued tightness.

Bayer Single Chain Balanced Valve Soot Cleaner

WITH THE Bayer Balanced Valve Soot Cleaner the balancing chamber above the piston disc impounds steam when the valve closes, thus relieving valve parts from shock. The valves remain *steam tight* because the dashpot action causes the valve to seat gently. Unbalanced valves close with a hammer stroke and soon become leaky.

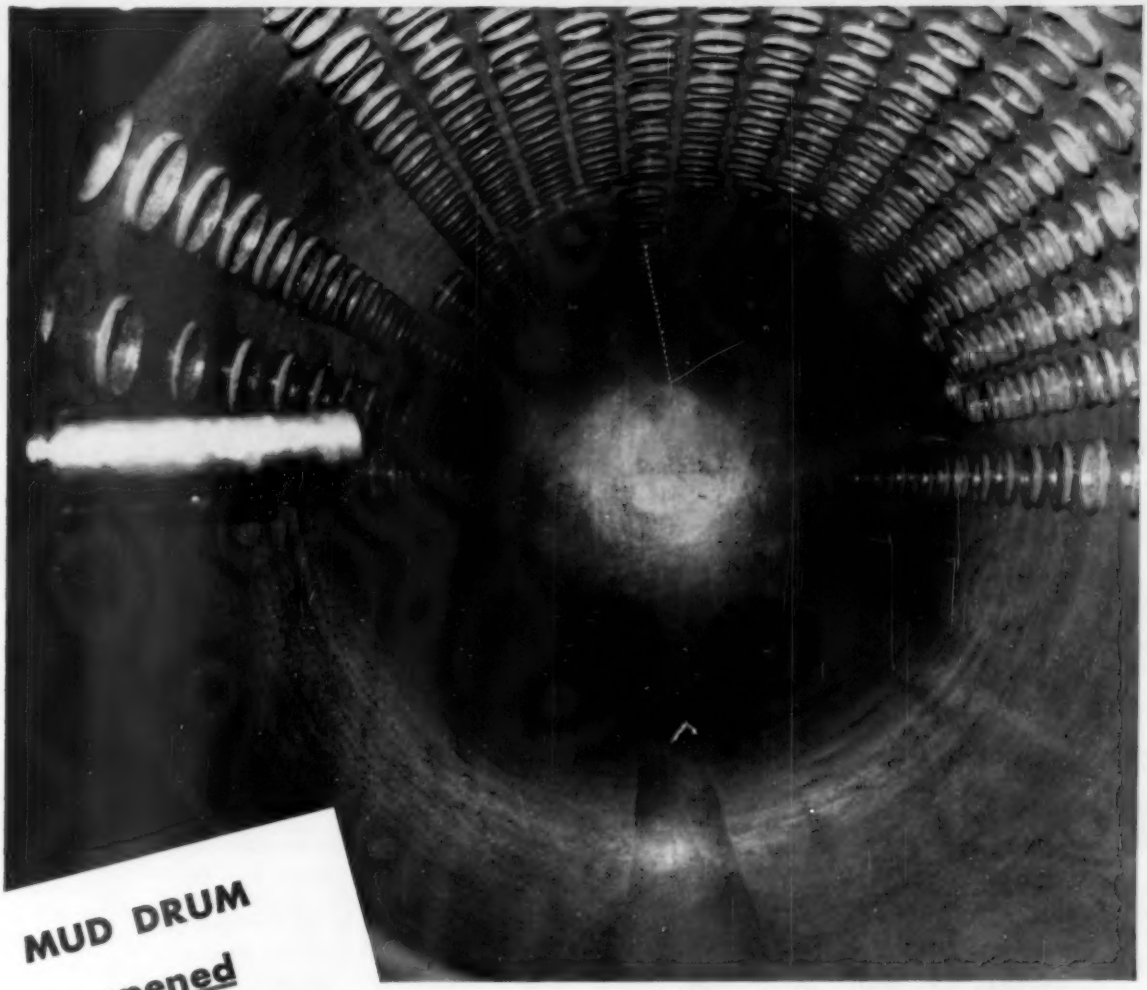
When stationary elements are used the Bayer stationary balanced valve head may be furnished. Thus all the cleaning elements of the entire soot cleaner system can be controlled by the Bayer quick-opening Balanced valves. This gives a uniform or standard valve controlled system and in addition, when high pressures require a reduction in pressure *at each individual element* this Balanced valve unit, whether used with a stationary or a revolving element, can be fitted with an integral orifice plate valve.

Piping connections can be kept in the same plane and undesirable bends or fittings avoided when the Bayer Balanced Valve is installed with both stationary and revolving elements.

Valve parts are standard and interchangeable and when high pressure heads are fitted with orifice plate regulating valves these parts are also interchangeable.

THE BAYER COMPANY

SAINT LOUIS, MISSOURI, U. S. A.



MUD DRUM
as opened
after one year
on line
with
THE *Nalco* SYSTEM

Unretouched photo of Nalco treated boiler at Georgia Institute of Technology, Atlanta, Georgia

● Calling this a mud drum serves only to identify its location . . . it is perfectly clean after a full year on line. The unretouched photo was taken immediately after the drum was opened. No wash-out was necessary. Not only is the drum free of scale and corrosion . . . Nalco sludge conditioning operated so effectively that even under the static, off-line draining condition, no sludge deposited in tubes or drums.

The Nalco System can get results like these, economically, in *your* plant—regardless of boiler size or pressure. Write or phone Nalco today for action on a complete water treatment program.

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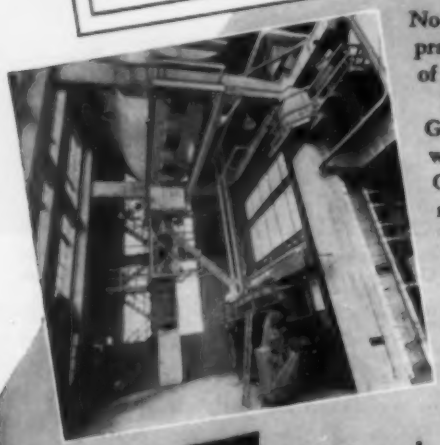
In Canada: Alchem Limited, Burlington, Ontario

THE *Nalco*®
SYSTEM . . . Serving Industry through Practical Applied Science

CUT COSTS WITH G-W SERVICE



G-W conveyor system with capacity of 60 tons per hour. System consists of a Rail and Truck Hopper, a 30-inch Apron Conveyor, Gravity Discharge Elevator, 250-ton Suspended Steel Bunker and a 2000-lb. Weigh Larry.

No two coal handling problems are exactly alike although practically all of them boil down to G-W's four basic types of storage and handling.

For example, at a large U.S. Government arsenal, G-W designed and installed the suspended steel bunker with a gravity discharge bucket elevator shown at left. Coal is carried on the upper run of the conveyor, permitting free access to machinery and maximum bunker capacity. A cab-type weigh larry with recording beam provides clean, economical operation.

4 BASIC WAYS TO CUT COAL HANDLING COSTS

No matter what your coal and ash handling problem is, from one of 4-basic types . . . Concrete Silos, Vitrified Tile Silos, Cylindrical Steel Tank, and Suspended Steel Bunker . . . G-W engineers can install the most efficient and economical storage and automatic handling system to fit your requirements of space, capacity and initial cost. Their recommendations to you, will be based on more than 140 years of design and engineering experience and on the performance records of hundreds of successful installations.

Fourteen interesting case histories, based on these 4 G-W basic designs, are described in Bulletin No. 300. Write for your copy, today.

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G-W HANDLES IT . . . faster . easier . cheaper

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background of champions . . . . BRICK

The stands may be steel, the walls concrete, but there'd be no World's Series crowd like this were it not for brick, and you'd have no money to pay for a seat.

Brick—refractory brick—is the fundamental and universal material of industry. It stands at the beginning of manufacturing, power, transportation . . . everything that's made or moved.

Meeting these needs, with the infinite variety of their requirements, calls for massive production facilities. But even more important, it calls for the application of the most advanced and intricate physical sciences.

The first we provide with plants located from coast to coast. The latter with the world's largest and most modern refractories research laboratory.

GENERAL REFRACTORIES COMPANY
Philadelphia 2

A COMPLETE REFRACTORIES SERVICE FOR STEAM GENERATION

Monolithic furnace linings of GREFCO plastic firebrick are economical and will provide long uninterrupted service. Three high quality mixes are available for various furnace conditions with a selection of well engineered refractory and high temperature alloy metal anchors for various combinations and thicknesses.

GREFCO plastics are manufactured at three strategically located plants in Pennsylvania, Missouri and Georgia. Stocks are maintained for prompt truck delivery at all company warehouses and dealers in principal cities.

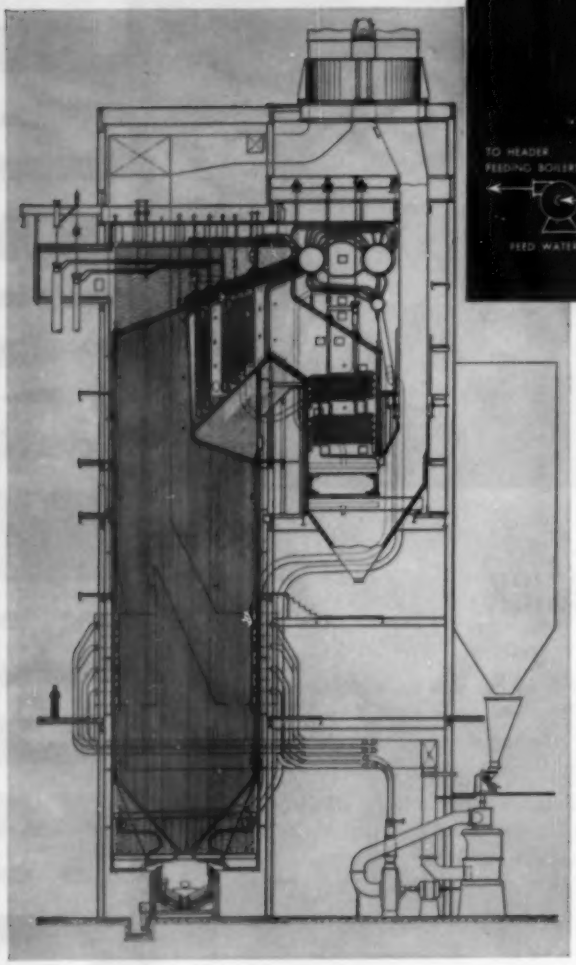
When you specify GREFCO you are assured of quality second to none. The world's finest and best equipped refractory laboratory is constantly developing new products and improving old ones. District laboratories constantly check raw materials and finished products. GREFCO places great emphasis on uniform high quality.

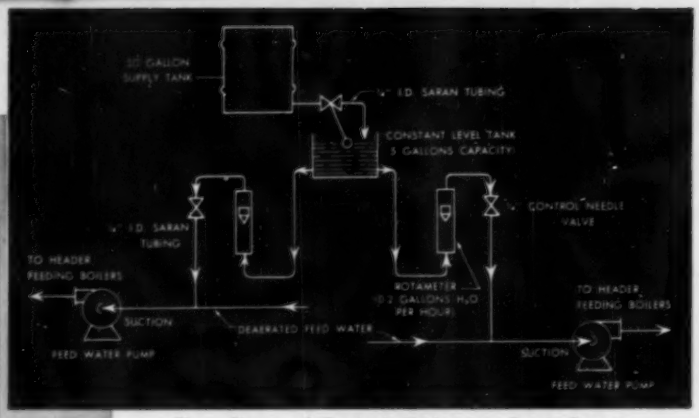
SUPER BRIKRAM MIX-G—a super duty quality plastic firebrick with a special binder which provides an airset when material is air dried. Provides high strength throughout the entire thickness of the wall or arch.

SUPER BRIKRAM—a plastic firebrick of super duty quality for furnace linings where conditions warrant the use of super duty quality. Has excellent resistance to spalling and high temperatures.

BRIKRAM—a plastic firebrick of high duty quality. Excellent for patching or complete furnace linings where conditions do not require a super duty quality refractory.

GENERAL REFRACTORIES





Flow Sheet of Typical Hydrazine Feed System

In both high-pressure and low-pressure steam plants, the following practical applications of hydrazine are now well established: (1) removal of trace oxygen from feed water, (2) preservation of superheater tubes in steam generating plants before they go into operation, (3) protection of idle boilers. Published reports of experience in this country as well as abroad, in power stations and industrial steam plants, indicate the efficiency of hydrazine treatment.

Hydrazine is a strong reducing agent which reacts rapidly with residual oxygen, eliminating all traces of this dissolved corrosive gas. Most important, the complete oxidation of hydrazine by dissolved oxygen results in water and nitrogen, imparting no additional "total solids" to the feed water. Moreover, hydrazine hydrate is an alkaline solution—a 1% solution of $N_2H_4 \cdot H_2O$ has a pH value of 9.9 at 25°C.

To get the latest information on the deoxygenation of steam systems with hydrazine, see your Mathieson representative or write today.

control oxygen corrosion... protect boiler systems with

HYDRAZINE HYDRATE

MATHIESON CHEMICALS
OLIN MATHIESON CHEMICAL CORPORATION
INDUSTRIAL CHEMICALS DIVISION • BALTIMORE 3, MD.

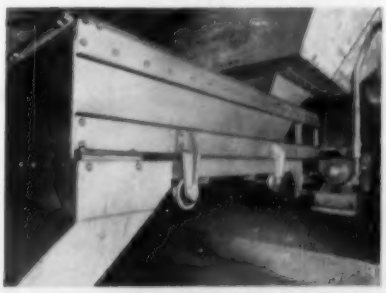
3080

General View of Tyrone Power Station
Kentucky Utilities Company
Sargent and Lundy
Consulting Engineers

Bartlett-Snow coal handling at Tyrone

● The illustration above shows the first 50,000 KW unit of a plant which is to be extended into a 170,000 KW station. All coal handling equipment including the track and reclaiming hoppers and grillage, duplex feeder, single plate feeder, conveyors, galleries, surge hopper and all supporting structures were detailed and fabricated in our shops and installed by us to Sargent and Lundy's specifications. For maximum efficiency and fixed unit responsibility, let the Bartlett-Snow coal handling engineers, with their long experience and complete facilities, work with you on your next job.

Track and Reclaiming Hopper, Crusher House, Stocking Out Conveyor and Storage Yard



Single Plate Feeder Discharging Reclaimed Coal to Main Belt Conveyor System

DESIGNERS ENGINEERS

BARTLETT-SNOW
CLEVELAND 5, OHIO

FABRICATORS ERECTORS

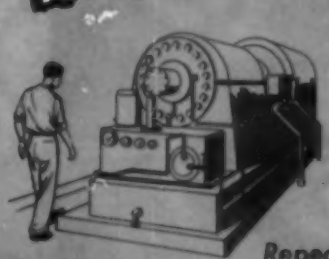
"Builders of Equipment for People You Know"

Facts* about

MEMO:
- of importance to Mechanical and Financial Engineers

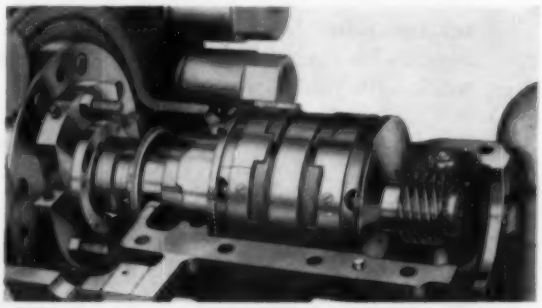
This plaque appears with increasing frequency in the Listing of Principal Power Plant Equipment...

MEMO:
- of importance to Operating and Maintenance Engineers



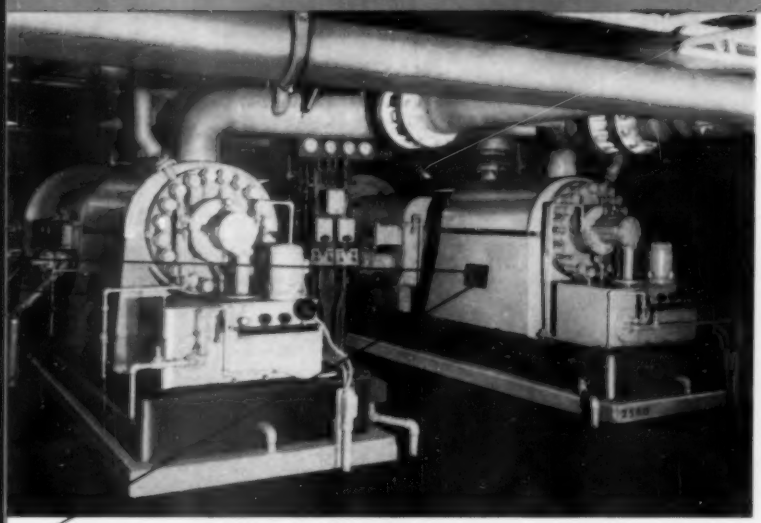
Your **PACIFIC BOILER FEED PUMPS** never need be dismantled unless there is a drop in capacity or head...then maintenance is easy...and because it is easy, the cost is low!

BEARINGS:
Can be inspected by simply removing the covers. Unitized internal assembly may be removed from the case and dismantled without heating the impellers or other parts.



Repeat orders from Utilities vary from 3 to 13 units—average 6 or more units!
Absolute evidence of Pacific's superiority in Performance—Economy—Service!

PACIFIC® BOILER FEED PUMPS



because it meets the Industry's 3 basic requirements... There is no cost compromise in the Design, Workmanship, Materials in

PACIFIC HIGH-PRESSURE BOILER-FEED PUMPS

● From 1950 to the present time more than 600 boiler feed pumps have been installed by Pacific for feedwater temperatures to 450° F ... capacities to one-million pounds-per-hour with discharge pressures to 2990 psig.

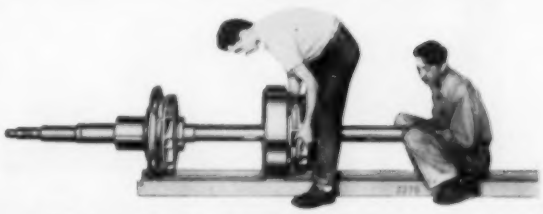
From the plain cylindrical case ... the unitized internal assembly ... the one, ring-type pressure joint ... the one, high pressure breakdown ... to bearings pressure lubricated with filtered, cooled oil, the design emphasizes simplicity with efficiency.

Precision workmanship is emphasized at every step from magniflux inspection of castings through boring ... turning ... grinding ... to dynamic balancing of rotating parts.

The chrome content of all parts fabricated from alloy steels is varied for depth hardening and resistance to corrosion-erosion.

MICROMETER CHECK-UP:

The accuracy of all internal bores can be checked *exactly*...not by guess...easily and quickly because of Pacific's superior design.



UNITIZED INTERNAL ASSEMBLY:

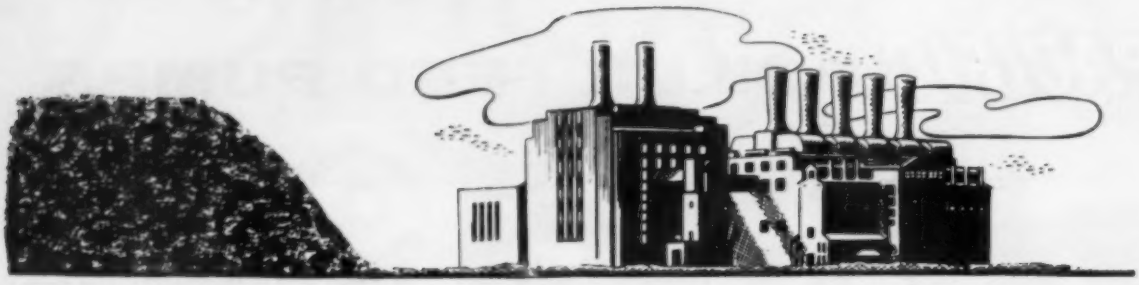
May be assembled by two men without the aid of a torch or other heating devices — thus eliminating shaft distortion due to uneven heating and cooling during assembly operation. There is no critical lateral adjustment of shaft after unitized internal assembly is installed in the case.

PACIFIC®

PACIFIC PUMPS INC. HUNTINGTON PARK CALIFORNIA

Export Office: Chanin Bldg., 122 E. 42nd St., N.Y.
Offices in all principal cities

9F-21



YOUR AIR SUPPLY MUST BE DEPENDABLE, TOO!

SPECIFY "BUFFALO" DRAFT FANS

FOR DELIVERY YOU CAN COUNT ON

The modern "Buffalo" Induced Draft Fan provides stable performance over a wide range of loads in today's high-resistance boiler systems. Its modified radial blade medium speed design, with low velocity through rotor and housing, is especially suited to counteract the severe abrasive action of hot fly-ash.

Since air is as important to combustion as fuel, why take a chance on your draft? "Buffalo" Mechanical Draft has more than earned its reputation for reliability over half a century in many of the biggest utility stations and plant boiler rooms. That's due to the "Buffalo" "Q" Factor*, the standard we've always held to: "build it up to the job, not down to a price." And users have reaped the benefits of longer fan service, fewer draft timeouts, easier maintenance — cheaper power output. "Buffalo" Induced Draft Fans, Forced Draft Fans, Primary Air Fans, Overfire Blowers and Diesel scavenger Fans are ready to do the same for you, too.

Write today for Bulletin 3750 for valuable engineering advice and facts on the fans for your power job!

**The "Q" Factor — the built-in Quality which provides trouble-free satisfaction and long life.*

BUFFALO FORGE COMPANY
170 MORTIMER ST. BUFFALO, N.Y.
Publishers of "FAN ENGINEERING" Handbook
Canadian Blower & Forge Co., Ltd., Kitchener, Ont.
Sales Representatives in all Principal Cities

VENTILATING AIR CLEANING AIR TEMPERING INDUCED DRAFT EXHAUSTING FORCED DRAFT COOLING HEATING PRESSURE BLOWING

J.B.—
These "Special" features are standard on 1500 and 2500 lb Edward Univalves.
R.J.P.

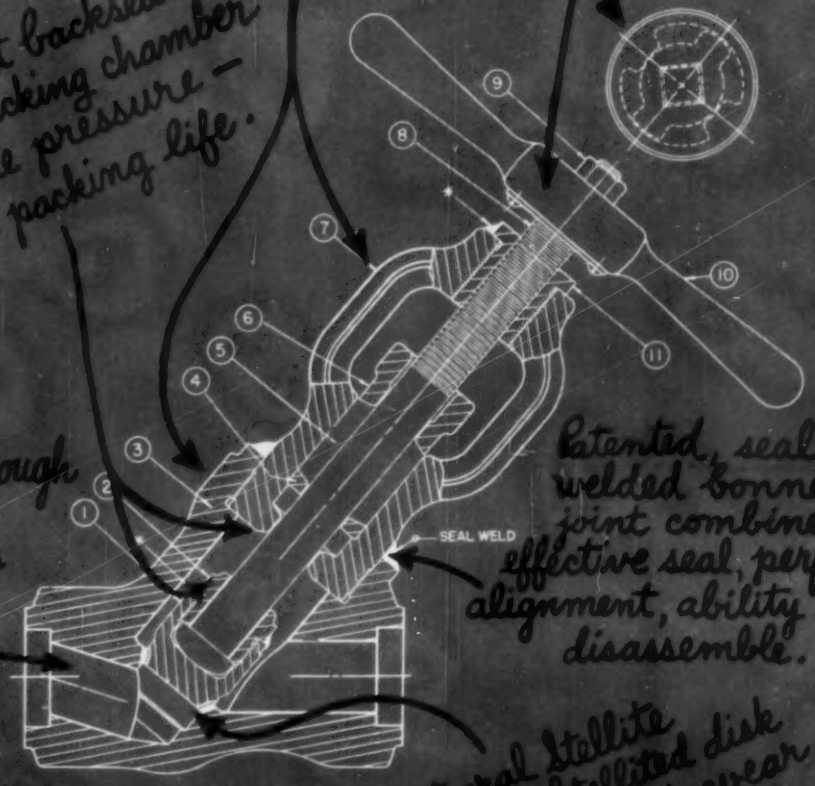
Impactor handle provides tight, effortless closing. No need for cheater.

Let's have Edward quote. Quality and performance are important.

All forged construction—no porous castings here.

ROCKWELL BUILT
Edward Valves

Line contact backseat isolates packing chamber from line pressure—prolongs packing life.



Straight-through design minimizes erosive wear due to turbulent flow—extends life.

Patented, seal-welded bonnet joint combines effective seal, perfect alignment, ability to disassemble.

Integral Stellite seat—Stellited disk resist wear.

LIST OF MATERIAL
QUANTITIES ARE FOR ONE GLOBE OR ONE ANGLE VALVE
WHERE A.S.T.M. SPECIFICATIONS ARE INDICATED THE LATEST REVISION APPLIES

PIECE NO.	NAME OF PIECE	NO. REQ'D.	MATERIAL	SPECIFICATIONS	EDWARD MS NO.
1	DISK	1	FORGED STEEL	A.S.T.M. A182 GRADE F11	227
2	DISK NUT	1	EVALLOY	A.S.T.M. A182 GRADE F6	213
3	BODY	1	FORGED ALLOY STEEL	A.S.T.M. A182 GRADE F11 (b)	227
				A.S.T.M. A182 GRADE F22 (b)	230
4	JUNK RING	1	STEEL-EVALIZED	A.I.S.I. C1020	123
5	PACKING RINGS		EVALPAK	HIGH TEMPERATURE PACKING	501
6	GLAND	1	FORGED STEEL	A.S.T.M. A105 GRADE II	111
7	BONNET	1	FORGED ALLOY STEEL	A.S.T.M. A182 GRADE F11 (b)	227
				A.S.T.M. A182 GRADE F22 (c)	230
8	STEM	1	EVALLOY	A.I.S.I. GRADE 416	261
9	STEM NUT	1	STEEL	A.S.T.M. A194 GRADE 1 OR 2	124
10	IMPACTOR HANDLE	1	MALLEABLE IRON	A.S.T.M. A47 GRADE 32510	322
11	YOKE BUSHING	1	BRONZE	A.S.T.M. B148 GRADE 9B HT	432
12	GLAND BOLT NUT	2	STEEL	A.S.T.M. A194 GRADE 1 OR 2	124
13	GLAND STUD	2	STEEL	A.S.T.M. A193 GRADE B7	206
14	GLAND BOLT LOCKNUTS	4	STEEL	A.S.T.M. A194 GRADE 1 OR 2	124

EDWARD VALVES, INC.
SUBSIDIARY OF ROCKWELL MANUFACTURING CO.
EAST CHICAGO, INDIANA

FORGED STEEL UNIVALVES
GENERAL ASSEMBLY
FIG.-3924 SIZES ½, ¾, 1, 1¼, 1½, 2

DRAWN: A.D.L.
CHK'D: J. Piet
APP'D: J. Strunck
DATE:

DRAWING NO. AE-3593-1

Edward builds Globe and Angle Stop, Non-Return, Check, Stop-Check, Gate, Blow-Off, Mudline, Relief, Hydraulic, Instrument, Gage, and Special Valves and Strainers.

Research-Cottrell

makes both

The choice of a straight precipitator or a combination mechanical-electrical precipitator for fly ash recovery depends on many factors—size and composition of the fly ash, efficiency desired, space available for the equipment, initial cost, etc.

Whatever your fly ash problem you can be sure of unbiased recommendations from Research-Cottrell, because we offer both types—and have done so for many years.

The cutaway drawings on the next page show several design features of both the straight Cottrell precipitator and the combination mechanical-electrical precipitator offered by Research-Cottrell.

These basic designs, as well as Research-Cottrell's custom engineering of each installation, are backed by over 40 years experience and over 500 fly ash collectors. For more details on this equipment write for Bulletins GB and FA.

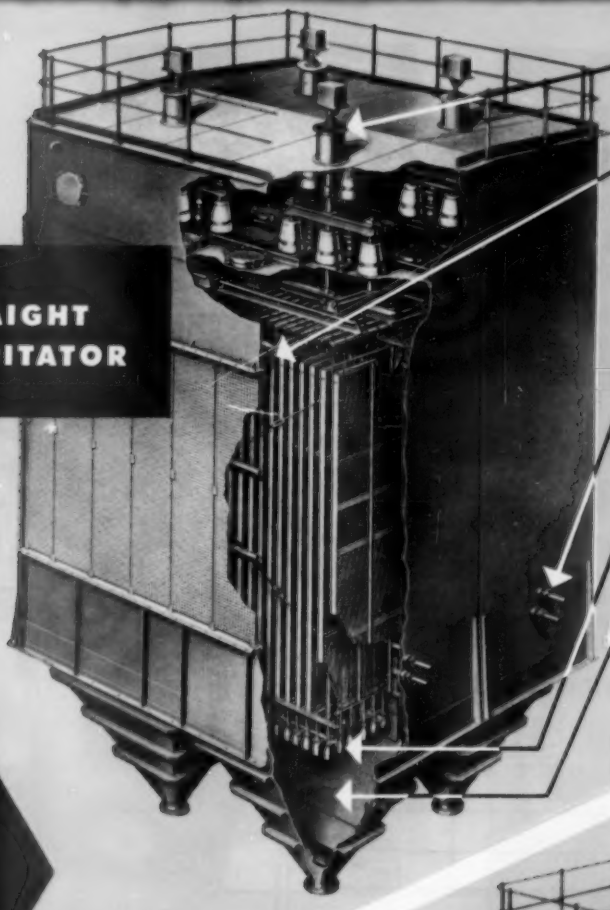
Precipitator is designed and constructed for many years of heavy-duty, all-weather service.

RESEARCH-COTTRELL, INC.

A Wholly Owned Subsidiary of Research Corporation

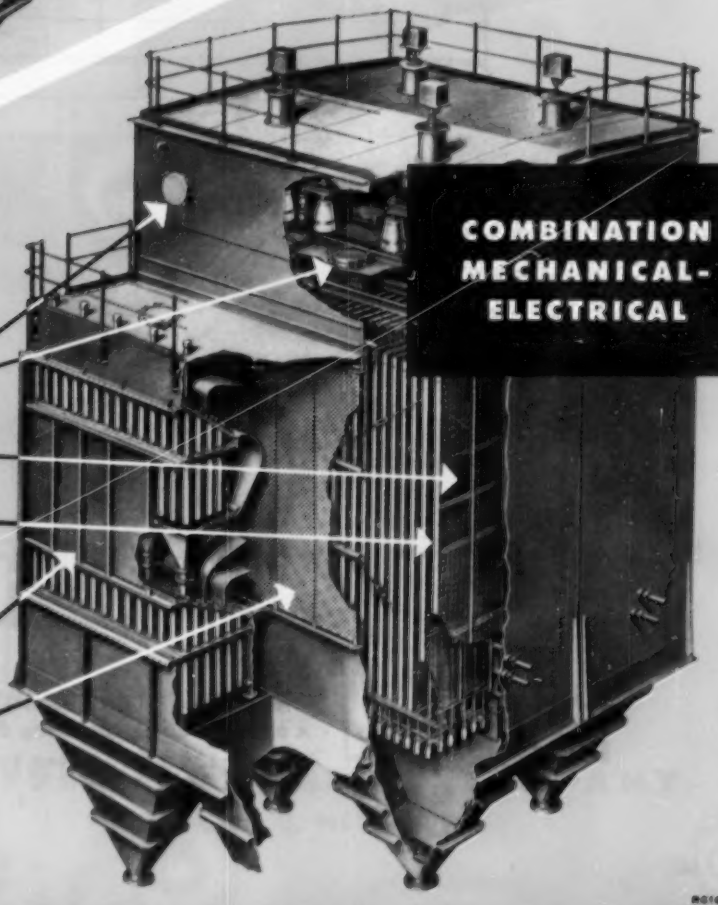
Main Office and Plant: Bound Brook, N. J. • 405 Lexington Ave., New York 17, N. Y. • Grant Building, Pittsburgh 19, Pa. • 228 N. La Salle St., Chicago 1, Ill. • 111 Sutter Bldg., San Francisco 4, Cal.

STRAIGHT PRECIPITATOR



1. Continuous, automatic discharge electrode rapping insures optimum performance.
2. Hook-type collecting electrode hangers, quickly installed, insure uniform distribution of rapper vibration throughout entire collecting surface.
3. Rapping puffs prevented by automatic and continuous cleaning of collecting electrodes with Magnetic Impulse Rapper (patents pending).
4. Plumb-bob discharge electrodes are individually weighted and positioned by a steadying frame for maximum efficiency.
5. Hopper baffle prevents gas sneakage around electrodes.

COMBINATION MECHANICAL-ELECTRICAL



6. Easy access to high tension equipment.
7. No moving parts in gas stream—minimizes maintenance.
8. End and intermediate baffles provide quiescent zones and prevent re-entrainment of collected dust.
9. Compact double-deck mechanical collector (patented) provides large capacity in a small area.
10. Double-deck mechanical collector design insures even gas distribution at precipitator inlet.

RC109

SURGEABILITY...

THE LATEST WORD IN WATER TREATMENT

Surgeability is defined as stability of performance under rapidly changing and unpredictable conditions including flow. This characteristic is vitally important in clarification and cold process softening installations. Surgeability is designed and built into the Graver Reactivator®.

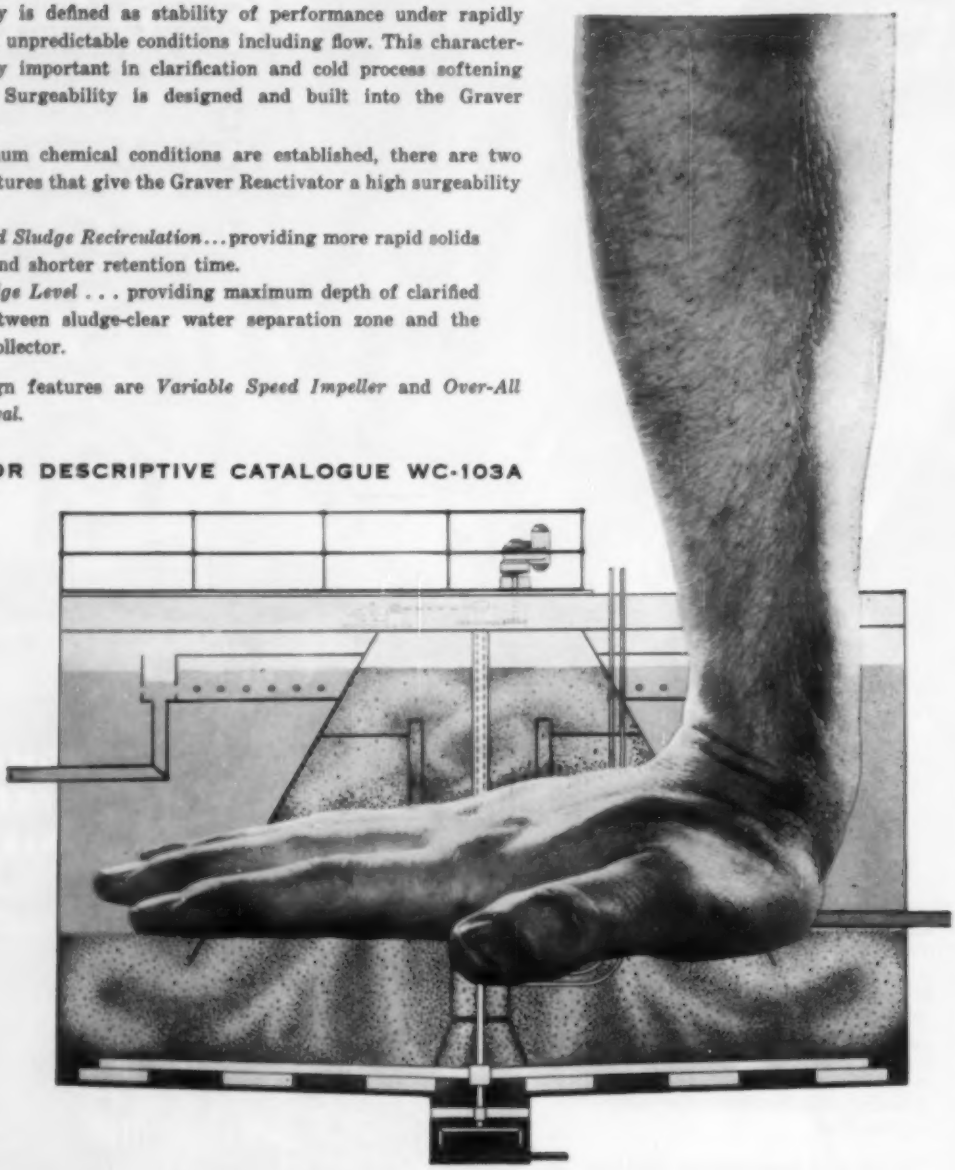
Once optimum chemical conditions are established, there are two important features that give the Graver Reactivator a high surgeability factor:

Controlled Sludge Recirculation... providing more rapid solids contact and shorter retention time.

Low Sludge Level . . . providing maximum depth of clarified water between sludge-clear water separation zone and the effluent collector.

Other design features are *Variable Speed Impeller* and *Over-All Sludge Removal.*

WRITE FOR DESCRIPTIVE CATALOGUE WC-103A



GRAVER

Department NK

GRAVER WATER CONDITIONING CO.

A Division of Graver Tank & Mfg. Co., Inc.

216 West 14th Street, New York 11, N. Y.

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FOR FIFTY YEARS

Specialists

IN IMPORTANT STEAM PLANT EQUIPMENT

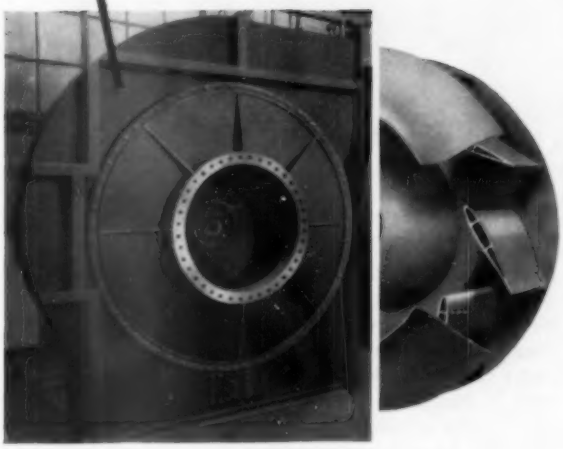
FORCED AND INDUCED DRAFT FANS

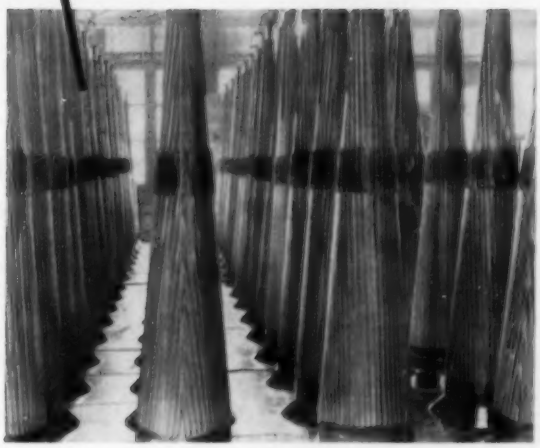
Complementing our several designs of GALEX Airfoil Type Draft Fan recently described is an extensive line of various types of fans with forwardly curved, straight radial, or backwardly curved blades. Thus, we are in position to offer soundly engineered fans for any draft requirement. The GALEX Fan, introduced by us in this country back in 1916, has been modernized and broadened in application particularly to take care of the more selective pressure-volume combinations required by today's boiler plant operations.

For problems of Fly Ash Control, we offer the Aerodyne Collector which is producing exceptionally gratifying results in some of the largest utilities in the country. Because of its positioning flexibility and adaptability to existing flue systems we suggest that you consider its use in connection with your fly ash problem.

Yes, on Draft Fans and Fly Ash Collectors, we are in a strong position to help you take care of your requirements . . . with plenty of experience to back up our recommendations.

FLY ASH AND DUST COLLECTORS





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POWER AND PROCESS PLANT EQUIPMENT

GREEN THE AIRFOIL TYPE FAN Galex FAN

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Representatives in Principal Cities

FUEL ECONOMIZER COMPANY,

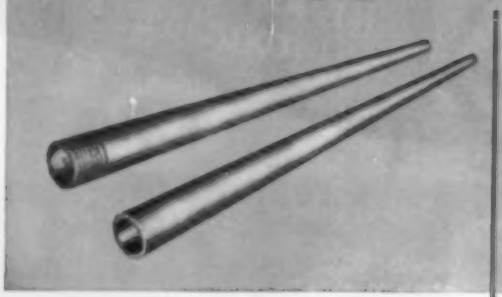
BEACON 3, NEW YORK

Iron... Steel... Bronze...
Special Alloys **and now...** *PLASTICS!*

WALWORTH PVC

globe and diaphragm valves

pipe and fittings



CORROSION-RESISTANT TO GIVE YOU NEW AND LASTING PROTECTION!

Walworth rigid plastic polyvinyl chloride valves, *and* fittings provide safe, trouble-free lines to handle wet and dry hydrogen gas—sulphur dioxide—dilute nitric acid—sulphuric acid—natural gas—sugar juice—milk—vinegar—tanning solutions and literally scores of other corrosive as well as noncorrosive materials in the chemical, petroleum, pulp, paper, food and other industries.

Walworth polyvinyl chloride valves *and* fittings are molded to the *same* rigid Walworth specifications by the *same* molder—the General American Transportation Corporation—of the *same* basic material,—Geon rigid vinyl from B. F. Goodrich Chemical. Rigid plastic pipe of the same materials and made by the same molder is also available. Consistent performance is therefore assured throughout *all*-Walworth PVC piping systems. Plastic valves, fittings, and pipe offer the following advantages:

1. **Exceptionally resistant to most salts, alkalis, and nonoxidizing acids at temperatures below 150° F.**
2. **High burst strength and impact resistance.**
3. **Nontoxic, and extreme low flammability.**
4. **Easy to install.**

Get the complete Walworth PVC product story. Write for brochure containing detailed specifications, characteristics, and application data.

WALWORTH

valves . . . pipe fittings . . . pipe wrenches

60 East 42nd Street, New York 17, N. Y.

WALWORTH COMPANY OF CANADA, LTD.

Toronto — Calgary

DISTRIBUTORS IN PRINCIPAL CENTERS THROUGHOUT THE WORLD

WHAT'S YOUR TROUBLE?

Each of these destroyed parts had to be taken out of service because of incomplete or inadequate water treatment. Replacement meant loss of steam production . . . new equipment expense . . . added labor-repair costs.

DEARBORN COMPLETE WATER TREATMENT SERVICE eliminates this by providing trouble-free water—a vital necessity to every user of industrial steam. Dearborn's many years of leadership in the field of water treatment will help keep your power plant operating economically.

CALL ON YOUR DEARBORN SALES ENGINEER for (1) analysis of raw water (2) recommendation of test procedures (3) proper treatment (4) a manually or automatically controlled feeding system.

Dearborn®

combatting corrosion wherever it occurs

Dearborn Chemical Company
Merchandise Mart Plaza, Dept. Com.
Chicago 54, Ill.

Please send me
- ☐ Internal Treatment Bulletin 5000
- ☐ Filmeen Bulletin 5013-A
- ☐ Dearborn "659" Bulletin 5008
- ☐ Have a Dearborn Sales Engineer call.

Name.....

Company.....

Position.....

Address.....

City..... *Zone*..... *State*.....

At Jersey Central Power and Light

A unique Hays built "two story" benchboard controls a 900,000 lb/hr multiple fuel fired boiler. Necessary control stations and miniature indicators are consolidated in a small space for one man operation, yet are easily accessible from inside the panel for servicing.

NEW DIMENSIONS IN COMBUSTION CONTROL

Dramatic results are being achieved by the nation's top

Today's boiler plant is only as efficient as the instrumentation which operates it. In selecting the correct equipment to assure completely automatic operation, to provide cost reductions through labor saving, and greater efficiency, the companies shown on these pages have looked to Hays. The newest in power plant design coupled with Hays workmanship and follow-through have given them the results they sought.

SKILLED FACTORY ENGINEERING

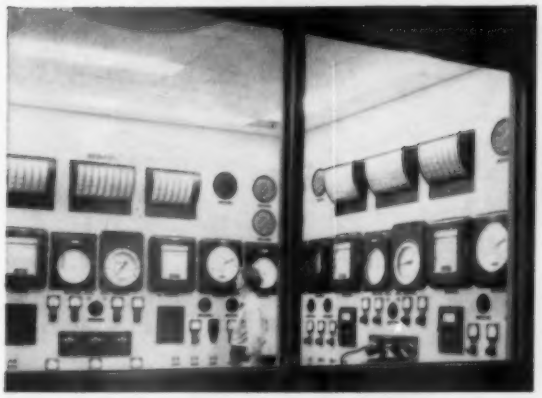
Hays systems are engineered to your specific requirements by a staff of specialists with years of experience on hundreds of boiler plants from the smallest to the largest. The particular instrument and control "package" necessary to handle your conditions is selected from the Hays product line; panel design, complete wiring, conduit, piping and control system diagrams are closely checked to see that they fit your requirements.

NATIONWIDE SERVICE

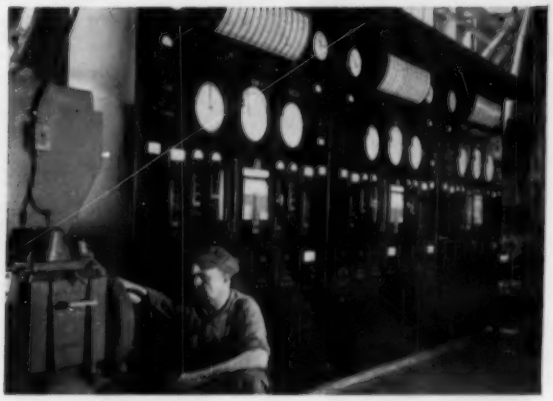
Service on Hays products is available throughout the country. Trained service engineers, from the factory or from Hays representatives in principal cities, can provide "start up" calibration and adjustment as well as subsequent periodic preventive maintenance service on your equipment.

For best results you will want to confer with Hays Sales Engineers in the earliest stages of your planning.

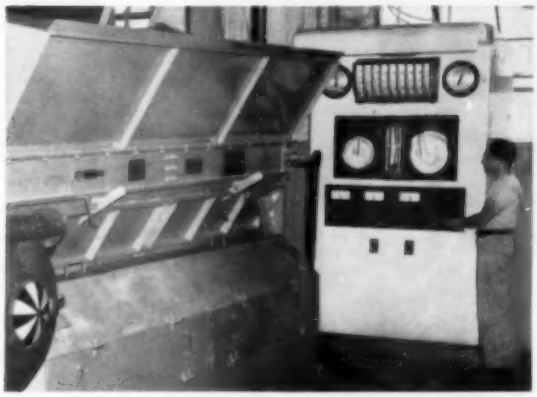
Write for complete information. Bulletin 55-605-83.



At Northern Indiana Public Service, the Hays system permits any desired allocation of load among three boilers, between the two cyclone furnaces of a given boiler and between the two fuels (coal and gas) being burned simultaneously in a given cyclone.



At Baldwin Locomotive Works, the Hays combustion control has aided substantially in saving 30,000 tons of coal per year and in reduction of maintenance. It is now possible to operate the power plant with 42 less men.



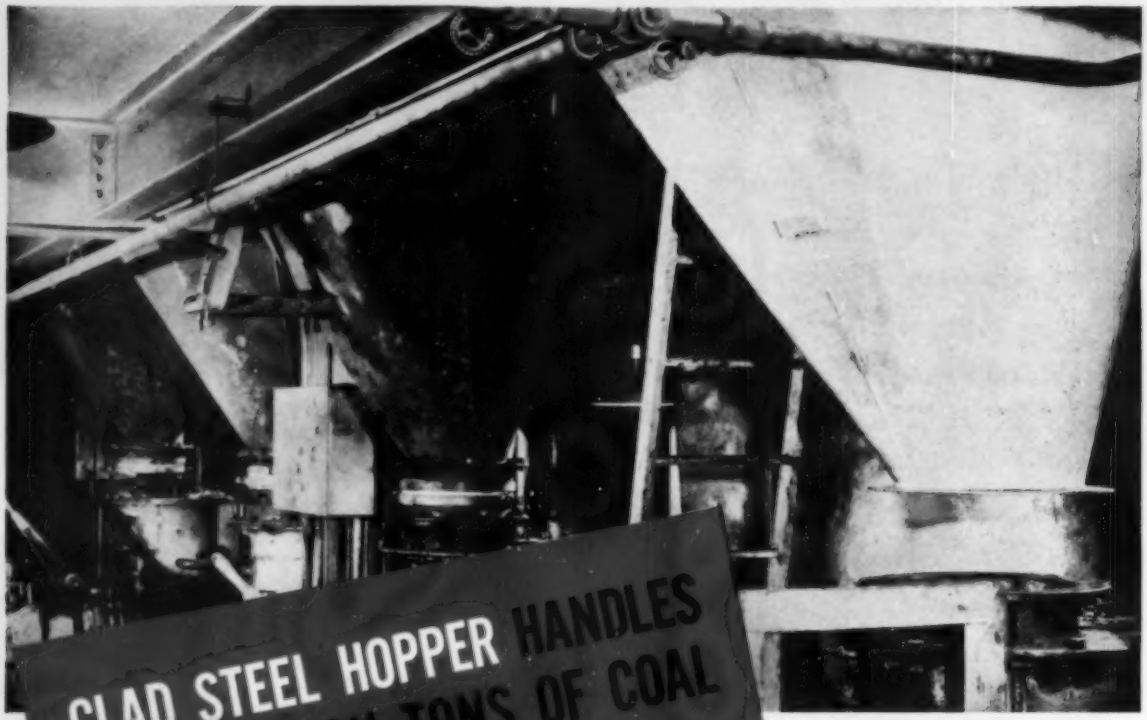
At Falstaff Brewing Corporation, modernization and Hays metering type control have resulted in boiler efficiency of 82%, fuel cost reduction of several hundred dollars per month, CO_2 up from 6% to 12%, and maintenance costs lowered 65%.

At Morton Salt Company, Manistee, Michigan, the fact that electricity doesn't freeze is vital in this semi-outdoor boiler which handles load swings up to 80,000 lb/hr at 85% efficiency with help of Hays electrically operated combustion control system.

utilities and manufacturing companies

At Louisiana Power and Light, a compact Hays B. T. G. control panel only 4 feet wide controls a giant 1,000,000 lb/hr boiler, turbine and generator! Instrumentation and control by Hays includes new electronic mercuryless flow meters and other electronic instruments for greater speed and accuracy.

THE
hays
CORPORATION
MICHIGAN CITY 1, INDIANA
Automatic Combustion Control • Ver-I-flow Meters and Ver-I-trol • Electronic Oxygen Recorders • CO_2 Recorders • Boiler Panels • Gas Analyzers • Combustion Test Sets • Draft Gages • Electronic Flowmeters • Miniature Remote Indicators • Electronic Feed Water Controls



CLAD STEEL HOPPER HANDLES HALF MILLION TONS OF COAL

Four stainless-clad steel hoppers at Niagara Mohawk's Huntley Station. The hopper at the extreme right replaces #634, which was recently removed for laboratory analysis.

After 9½ years of continuous service—handling an estimated 500,000 tons of coal—hopper #634 at Niagara Mohawk's Huntley Station was removed in 1954 for laboratory analysis. It was found to be in perfect condition. This stainless-clad steel hopper had been installed in 1945 to reduce hangups as well as to relieve heavy repair costs. Examination showed no measurable loss of gage, no repairs and a smoother surface than at the time of installation.

Although coal is highly abrasive and when wet inevitably creates sulfuric acid corrosion, this Type 304 stainless-clad steel hopper showed no signs of the abrasive and corrosive effects of coal over the nearly 10-year period. Because of the exceptional performance of stainless-clad steel in this hopper, it has since been specified for other coal handling equipment in the Niagara Mohawk system.

Stainless-clad steel—a layer of solid stainless integrally bonded over its entire surface to a strong, low-cost carbon steel backing—provides all the benefits of solid stainless plate at greater economy. It means long-term savings, too, for clad steel equipment should last the life of the boiler.

If you would like to find out how clad steel can best serve you, write for Bulletin 740. Lukens Technical Service engineers can provide direct assistance to your builders or your own engineers in the selection and fabrication of the best in coal handling equipment. For the name of a qualified equipment builder, write to Manager, Marketing Service, 684 Lukens Building, Lukens Steel Company, Coatesville, Pennsylvania.

LUKENS

STAINLESS-CLAD STEELS

FOR INTERIOR COAL HANDLING EQUIPMENT

LUKENS STEEL COMPANY, COATESVILLE, PENNSYLVANIA

PRODUCER OF THE WIDEST RANGE OF TYPES AND SIZES OF CLAD STEELS AVAILABLE ANYWHERE

RCA Industrial TV

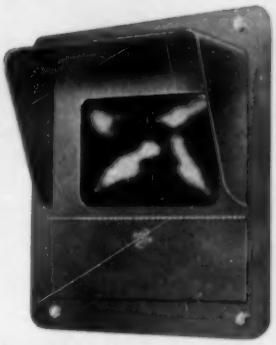
Now Industry-Designed for Every **Heavy-Duty Job**

SMALL, RUGGED CAMERA—

only 11" x 5⅜" x 5¼"—goes anywhere—sees with amazing definition — picks up fine meter readings—shows practically any operation or process in detail.

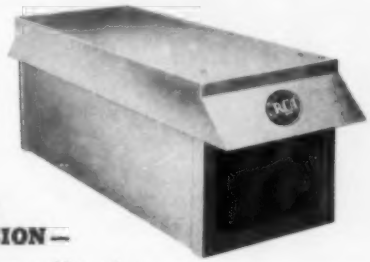
NEW ITV-6

High Resolution, Low Maintenance Unit Now Available



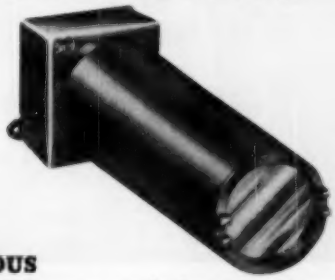
PANEL-MOUNTING MONITOR—

fits your present control board—becomes an integral part of your instrumentation setup. All camera functions are controlled at monitor. Six-hundred-line resolution for high-definition image.



FOR OUTDOOR SUPERVISION—

new weatherproof housing protects camera from cold, heat, snow, and rain—makes RCA Industrial TV a true round-the-clock, round-the-calendar instrument.



FOR HAZARDOUS CONDITIONS—new explosion-proof housing lets you place your camera in any location too hazardous for your personnel.

FOR HIGH-TEMPERATURE OPERATIONS—

RCA's new water-cooled lens permits direct viewing of operations where temperatures run up to 3000°F.

FULL LINE OF ACCESSORY AND CONTROL EQUIPMENT DESCRIBED IN NEW, FREE BOOKLET

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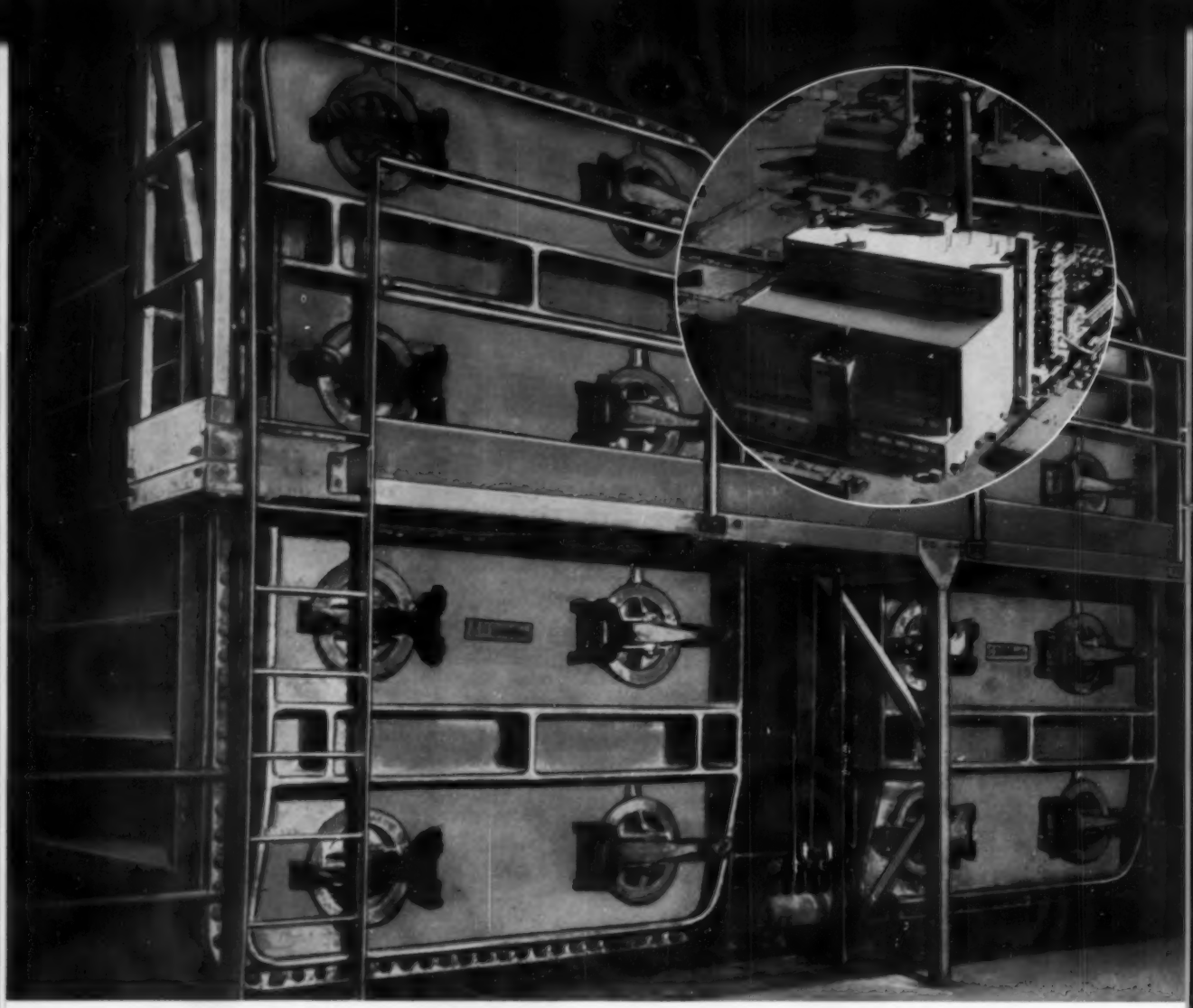
Company_____

Address_____

City and State_____



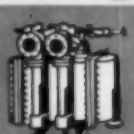
STEAM CONDENSERS at
CONSOLIDATED EDISON'S ASTORIA STATION
feature C. H. WHEELER ADVANCED DESIGN

C.H. Wheeler

Steam Condensers and Auxiliaries

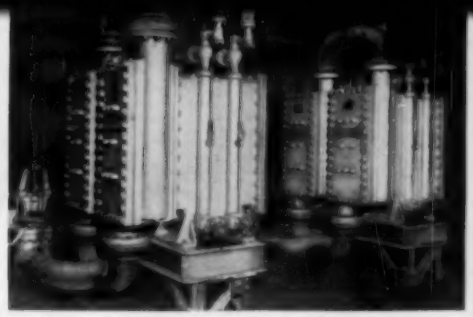
Centrifugal, Axial and Mixed Flow Pumps

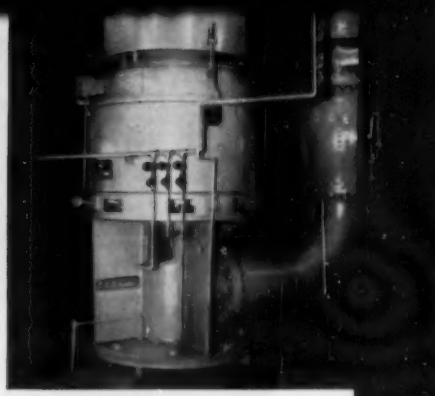
Steam Jet Ejectors High Vacuum Process Equipment

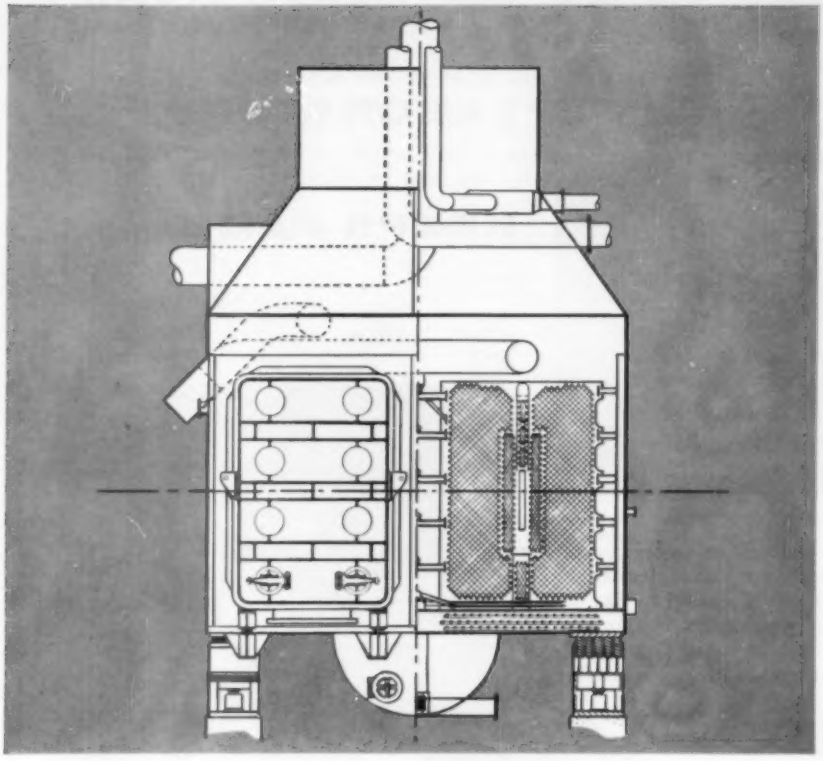

Marine Condensers and Ejectors

Steering Gear

Deck Machinery Marine Pumps







TOP LEFT — These four condenser circulating water pumps, installed at the Astoria Station of Con Edison Company in New York, are of the removable type with under floor discharge. Each pump has a capacity of 68,500 GPM; 16' TDH: 233 RPM.

CENTER — Operating at Con Edison's Astoria Station in New York, each 2 stage element of this twin element, 2 stage air ejector, is designed to remove 37.3 lbs. per hour of air saturated with water vapor, from condenser at 1" mercury absolute. Inter and after condensers are in separate shells.

TOP RIGHT — One of four 18"x20" vertical salt water service pumps in operation at Con Edison's Astoria Station. Capacity is 8,000 GPM; 100' TDH: 880 RPM.

LEFT — Arrangement of Tube Bundles in C. H. Wheeler Dual Bank Steam Condensers installed at Consolidated Edison's Astoria Station. Each unit is designed to condense 950,000 lbs. of steam per hour.

Two dual bank steam condensers of divided water box design, like the one shown above, are installed by C. H. Wheeler at Consolidated Edison Company's Astoria, N.Y. Station. Each unit contains 15,450 tubes with 105,000 sq. ft. of condensing surface. One of the principal features of these C. H. Wheeler Steam Condensers is the advanced design of layout for the tube banks. Path of steam travel is shorter and distribution to the tubes is greater, resulting in smaller pressure drop.

C. H. Wheeler specially engineered each condenser unit to facilitate the quick start requirements of the Consolidated Edison system. Steam can be dumped directly from the boiler during periods when the boilers are being brought up to temperature corresponding to the turbine parts.

C. H. Wheeler has been singularly successful with advanced designing in these extremely large units, achieving minimum pressure drop in the tube bank, along with generous steam distributing space. The C. H. Wheeler design is also well suited for deaerating where there are rigid specifications on oxygen content in the hotwell discharge.

There is a reason for C. H. Wheeler's leadership in the field of steam power generation. We urge you to investigate C. H. Wheeler to insure your success with your next important project.

C. H. WHEELER MANUFACTURING COMPANY
19th & Lehigh, Philadelphia 32, Pa.

FACTORS TO BE CONSIDERED IN SELECTION OF HIGH TEMPERATURE STEAM POWER PIPING	
STEEL MANUFACTURE AND RAW MATERIALS PROCESSING FACTORS	MELTING AND CASTING HOT WORKING HEAT TREATMENT INSPECTIONS ACTUAL EXPERIENCE WITH SPECIFIC COMPOSITION
FABRICATION FACTORS	HOT BENDING, FORGING HEAT TREATMENT WELDING POST HEAT TREATMENT MACHINING INSPECTIONS ACTUAL EXPERIENCE WITH SPECIFIC COMPOSITION
SERVICE FACTORS	HIGH TEMPERATURE LOAD CARRYING CAPACITY (x 1000) STABILITY WITH TIME GENERAL

AS POWER PIPING BECOMES MORE CRITICAL

M. W. KELLOGG'S METALLURGICAL LABORATORY KEEPS PACE

As shown above, there are many factors—all increasingly important to steam-electric power plants—in selecting materials for tomorrow's main and reheat steam piping needs. Prepared by M. W. Kellogg's metallurgical laboratory, and reproduced here only in part, this chart indicates the extent to which Kellogg's metallurgical laboratory supports Kellogg's fabricating facilities in meeting the challenge of higher temperatures and pressures.

One recent Kellogg assignment, by a leading public utility, is the problem of selecting a super alloy for main steam piping to operate at 5500 psi and 1200 deg. F. A testimonial to the leadership and experience of the M. W. Kellogg metallurgical laboratory, this problem will include selection of special welding materials, welding techniques, and heat treating procedures.

Working closely with power companies at every stage of such problems is the prime function of Kellogg's metallurgical laboratory, and is carried through to periodic inspection of the piping in service. We welcome the opportunity to acquaint you with these facilities.

FABRICATED PRODUCTS DIVISION

THE M. W. KELLOGG COMPANY, 225 BROADWAY, NEW YORK 7, N. Y.

The Canadian Kellogg Company, Ltd., Toronto • Kellogg International Corporation, London

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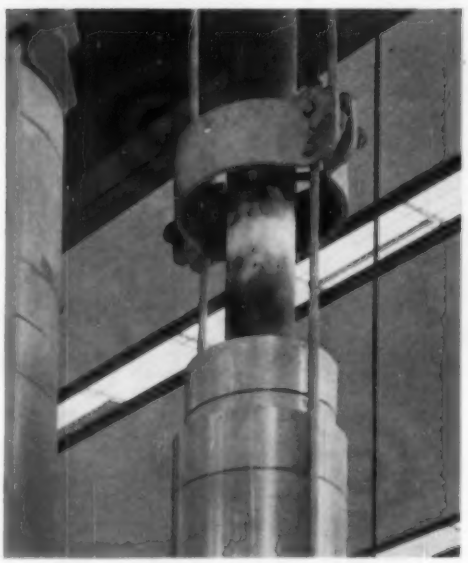


The soundness of Kellogg's metallurgical studies prior to fabrication is evident from the condition of the welds on this stainless steel power piping when inspected recently. In service for 18 months at 2350 psi and 1100 deg. F., over 70 butt welds made with Kellogg's K-Weld* process were found to be in perfect condition. *(Photo at power station, Kearny, N. J., courtesy Public Service Electric & Gas Co.)*

POWER PIPING—THE VITAL LINK

HALL LABORATORIES, INC.—A SUBSIDIARY OF HAGAN CORPORATION, PITTSBURGH, PENNSYLVANIA

Hall Industrial Water Report

VOLUME 3 OCTOBER 1955 NUMBER 5

It Takes a Lot of Water Conditioning To Manufacture Paper

Ten billion tons of water are required annually for many uses in the papermaking industry. Production has increased from less than one ton per day in the first mill in the United States to 26,656,000 tons in 1954. Water-connected problems of all kinds are handled in over two hundred papermaking plants by Hall service engineers.

Pollution Abatement Program Cited by State Authorities

In connection with its waste disposal problem, an eastern paper manufacturer with the advice of Hall Laboratories set up an investigative and remedial program supervised by Hall staff engineer Herman A. Reda.

The plant had been discharging its industrial waste waters into a waterway supplying a city of 130,000. Pollution was so severe that septic conditions developed when there were periods of low flow. The fact that potable supplies were affected made the situation quite serious.

The removal of contamination, required by the state, was accomplished by utilizing air flotation units to clarify the water and remove the pulp fiber. This equipment functioned so efficiently that both the water and the fibers of pulp could be re-used. The selection of this equipment was based on pilot plant studies which indicated a 97.1 percent removal of suspended solids and a 95 percent reduction in oxygen consuming material.

$100,000 per year is the plant's estimate of the value of the reusable pulp recovered by the in-plant changes and treatment processes recommended by Mr. Reda. Sufficient clarification of white water to permit re-use on the paper machines reduced the plant over-all water consumption.

The reduction of wastes at their sources was, of course, one of the most important results of this work. In their report to the General Assembly of Delaware, the Commission stated that the cooperation received from industry in this particular study, investigation, and follow-up was most satisfactory and exemplary.

Maintenance Cost Reduced

A Canadian newsprint plant was running efficiency tests throughout the plant. At the suggestion of Hall engineer J. C. Skerrett, the plant carried out a three-month test on a paper machine to determine the effect of Hagafilm® in improving heat transfer by cleaning out old corrosion products and controlling return line corrosion.

Pleased with the results of this test, the plant decided to run a test on their Flakt dryer, a separate unit, where leakage due to corrosion was a problem. Overtime for weekly welding of the interconnecting piping of the steam and condensate headers was a costly item.

Leaks stopped within one week after a Hagafilm feed of 2ppm was started, and since there has been no recurrence after six more weeks of operation, it is obvious that maintenance has been reduced to almost the vanishing point.

Hall Engineer Reports on Service

Putting a new boiler into operation can bring up some unexpected problems as the following reports from a Hall engineer on another paper plant show.

Discussed recommendations outlined in my letter to the plant. Lined up plant for boiling out new boiler. Also discussed variations in raw water characteristics.

Returned to plant for initial operation of hydrogen zeolite unit. Suggested that plant start to decrease rate of blowdown as more of the blended water is used. Boiler-water test results showed deficiencies of phosphate and sulfite. Had them increase feed of chemicals.

Went over operation of sodium-hydrogen zeolite unit setup. Found that system was cut into service only twice a day as the clear well level did not drop appreciably. Checked clear well water to determine whether or not raw water was getting into the system and found it O.K.

Learned that the plant had been operating for four days with an acid boiler water. Investigation indicated the cause to be faulty operation of the flow control valve. Immediately cut off the hydrogen zeolite unit and went to straight sodium zeolite make-up.

Called to check on plant since we eliminated the acid in the boiler water. Boiler-water alkalinities now around 16 ml and plant is again blending the sodium-hydrogen zeolite water.

A while ago I alerted the plant to the fact that something was wrong in the setup because of unexplainable high alkalinity and high phosphate consumption. My checks on the clear well and condensate revealed nothing. However, about ten days ago, things became very upset and clear-well water indicated contamination. Investigated and found that main sewer line carrying backwash water from raw-water filters was broken and that there were cracks in the clear well. The sewer runs alongside the clear well. Contamination occurred whenever level in the clear well was low, allowing water to seep in.

Director of Hall Laboratories Receives A. S. T. M. Award

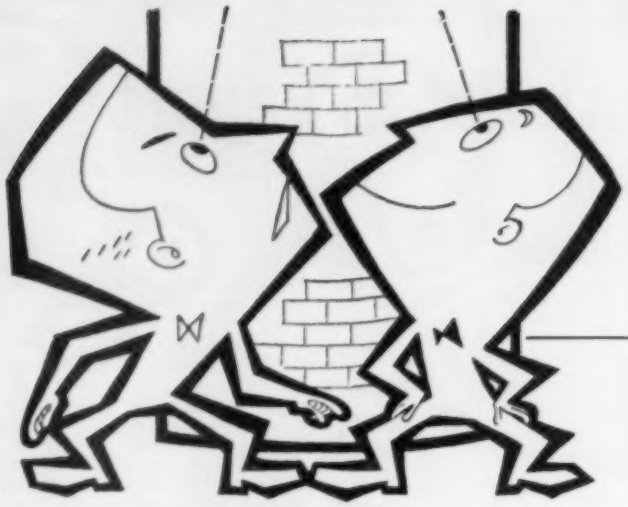
Dr. Everett P. Partridge has received the 1955 Max Hecht award of the American Society for Testing Materials for "30 years of outstanding contributions to the technology of industrial water."

Industrial Water Problems Require Special Handling

There are no "stock answers" to industrial water problems. For information write, wire or call Hall Laboratories, Inc., Hagan Building, Pittsburgh 30, Pa.

Water is your industry's most important raw material. Use it wisely.

Hall Laboratories, Inc.—Consultants on Procurement, Treatment, Use and Disposal of Industrial Water



Your chimney never smokes any more. Did you change to another fuel?

We just changed to another kind of coal. And man! Does it make a difference! No smoke. No clinkers. No trouble. And very few ashes.

What kind of magic coal is this?

It's one of the superior quality coals produced on the Chesapeake and Ohio. But the important thing is that it is exactly right for our type of installation.

Say, I've got to look into this! We're always having boiler room trouble at our plant.

Picking the right coal is a job for an expert. I never realized there were so many things to consider. Size, moisture, sulphur, ash softening temperature, etc., as well as BTU's.

Why don't you write to the C&O coal people? Tell them your problem and describe your boiler equipment. They'll help you find the very best coal for your particular condition.

P.S. There's a lot more to buying coal than the cost per ton. Why not contact coal producers on the C&O to solve your particular fuel requirements, or write to: R. C. Riedinger, General Coal Traffic Manager, Chesapeake and Ohio Railway Company, Terminal Tower, Cleveland 1, Ohio.

Chesapeake and Ohio Railway

WORLD'S LARGEST CARRIER OF BITUMINOUS COAL

this is "life insurance" for boilers

It's a good "policy" to protect your valuable boilers with YARWAY Boiler Level Indicators.

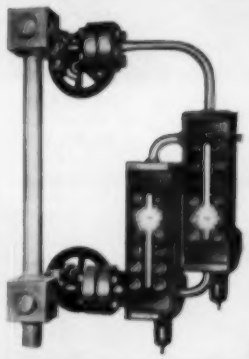
Instant . . . accurate . . . continuous remote readings of boiler water levels are available on the instrument panel or wherever you wish in the plant.

YARWAY's new "wide vision" face gives brilliant readings from any angle . . . and the pointer is always visible, even at extreme high and low water levels.

For brilliant "shines like a star" readings on the boiler drum you'll want to use YARWAY Flat Glass Gages with Type "M" Illuminators.

From drum to panel and at all remote locations, YARWAY equipment gives you the safest boiler protection you can buy—proved beyond doubt in nearly 10,000 installations.

Yarway Remote Liquid Level Indicator. Write for Yarway Bulletin WG-1824.

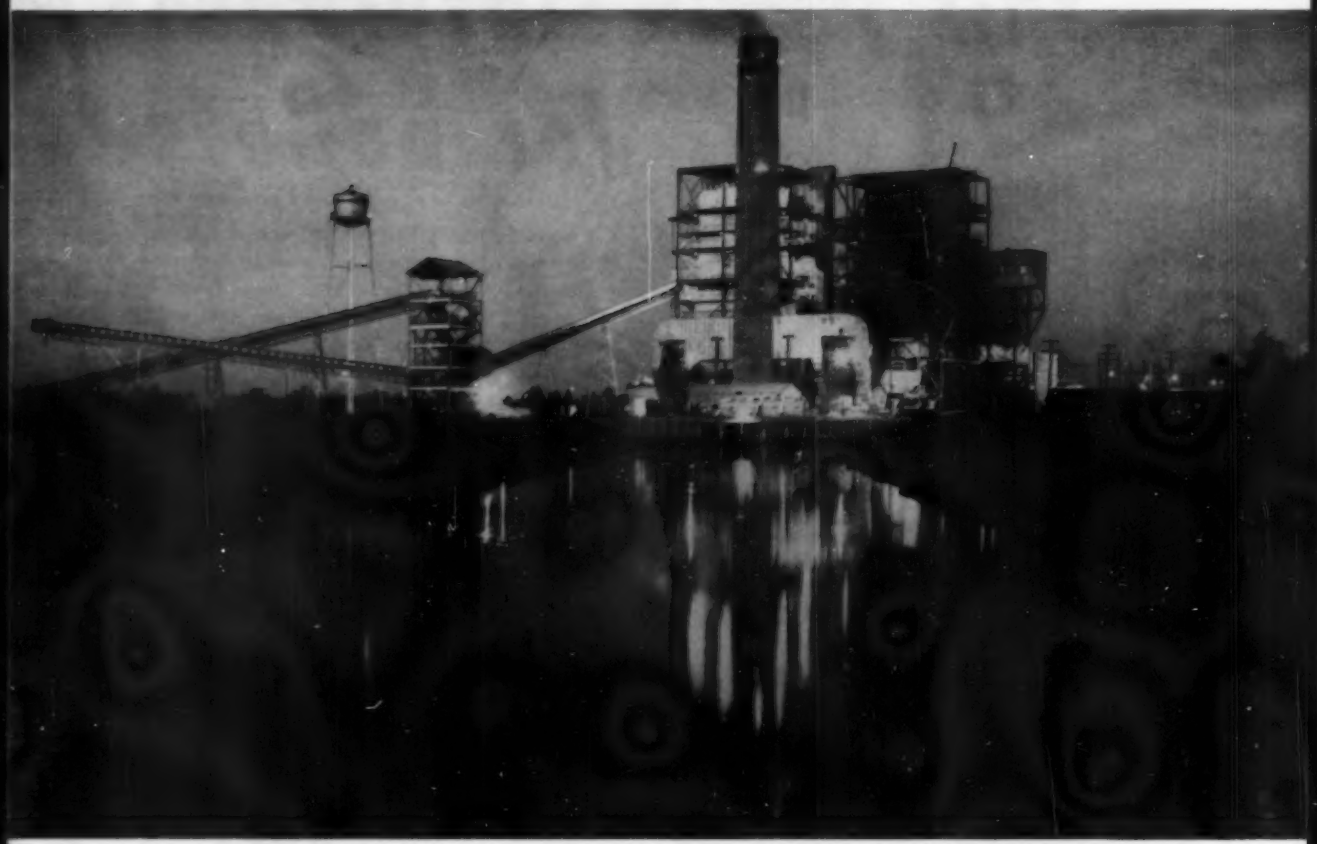


Yarway Flat Glass Water Gage with Type "M" Illuminators. Write for Yarway Bulletin WG-1812.

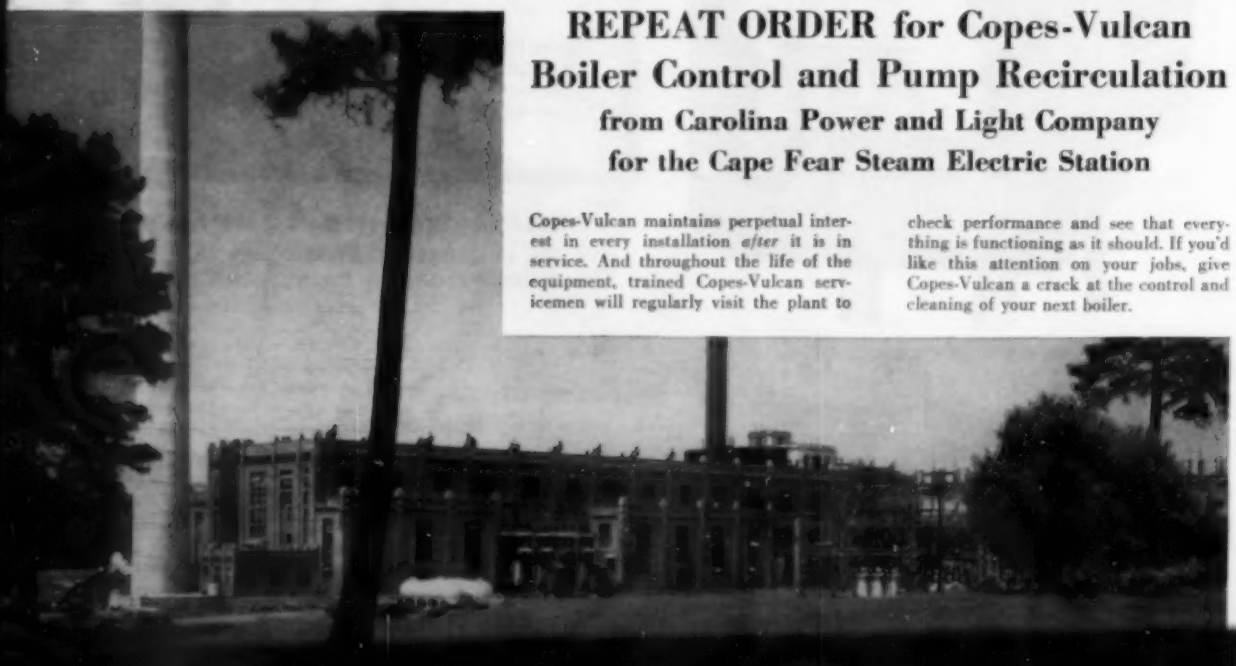
YARNALL-WARING COMPANY
100 Mermaid Avenue, Philadelphia 18, Pa.
BRANCH OFFICES IN PRINCIPAL CITIES

YARWAY **steam plant equipment**

Copes-Vulcan helps to make MORE



THE ALL-OUTDOOR Louis V. Sutton Steam Electric Generating Plant of the Carolina Power & Light Company at Wilmington, N. C. Copes-Vulcan Combustion Control, Boiler Feed Water Control, and Automatic-Sequential Soot Blowing help to maintain maximum boiler efficiency.



REPEAT ORDER for Copes-Vulcan Boiler Control and Pump Recirculation

from Carolina Power and Light Company for the Cape Fear Steam Electric Station

Copes-Vulcan maintains perpetual interest in every installation *after* it is in service. And throughout the life of the equipment, trained Copes-Vulcan servicemen will regularly visit the plant to check performance and see that everything is functioning as it should. If you'd like this attention on your jobs, give Copes-Vulcan a crack at the control and cleaning of your next boiler.

POWER FOR CAROLINA

At Carolina Power & Light Company's new outdoor installation, the Louis V. Sutton Steam Electric Generating Plant, steam is generated in two coal-fired boilers designed for 1750 psi at 1005 F. Unit 1 is a Combustion Engineering steam generator with a design load capacity of 950,000 pph. Unit 2 is a radiant-reheat Babcock & Wilcox boiler designed for 900,000 pph, with a reheat to 1005 F. Copes-Vulcan control helps keep these steam generators efficient.

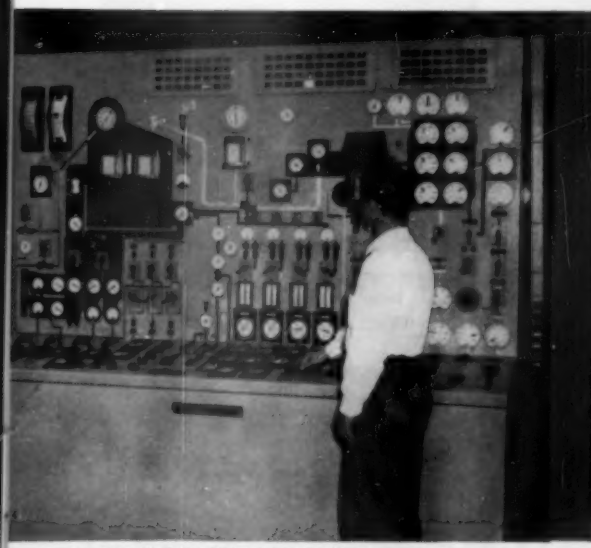
BOILER CONTROL

A Copes-Vulcan Combustion Control System accurately regulates the fuel and air for proper combustion. Copes Type 3-L Feed Water Control matches the feed flow to the steam demands and maintains a constant drum level. Copes provided 10-inch, 1500 pound standard motor-operated feed water by-pass control valves. Copes-Vulcan control and valves give automatic recirculation for protection of three boiler feed pumps.

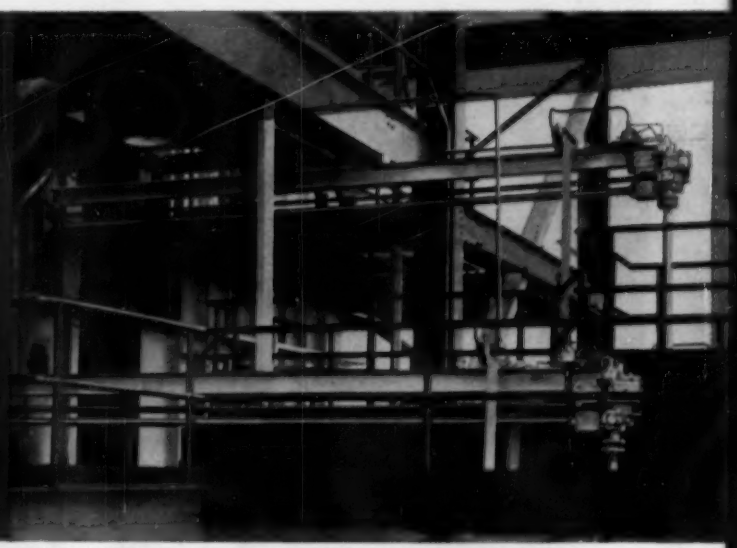
BOILER CLEANING

The Vulcan Automatic-Sequential Soot Blowing thoroughly cleans the heating surfaces. Air is the blowing medium in both units. Air motors drive the blowers in Unit 1; Electric motors drive those in Unit 2. Cleaning elements include Vulcan long retractables, wall deslaggers, rotaries, and air preheater cleaning controls.

Write for complete information about Copes-Vulcan Boiler Controls and Soot Blowers.



COMPACT OPERATING PANEL. There is one operator in the central control room at the Louis V. Sutton Generating Plant.



DUAL-MOTOR DRIVE on these Vulcan Long Retractables and the Vulcan Wall Deslaggers give more complete cleaning than single-motor drive, leaving *no* surface unblown.

COPES-VULCAN DIVISION

CONTINENTAL FOUNDRY & MACHINE COMPANY

ERIE 4, PENNSYLVANIA

We believe
ONLY THE HIGHEST QUALITY OF PRODUCT AND SERVICE TO OUR CUSTOMERS CAN BUILD A REPUTATION WORTHY OF OUR EFFORT.
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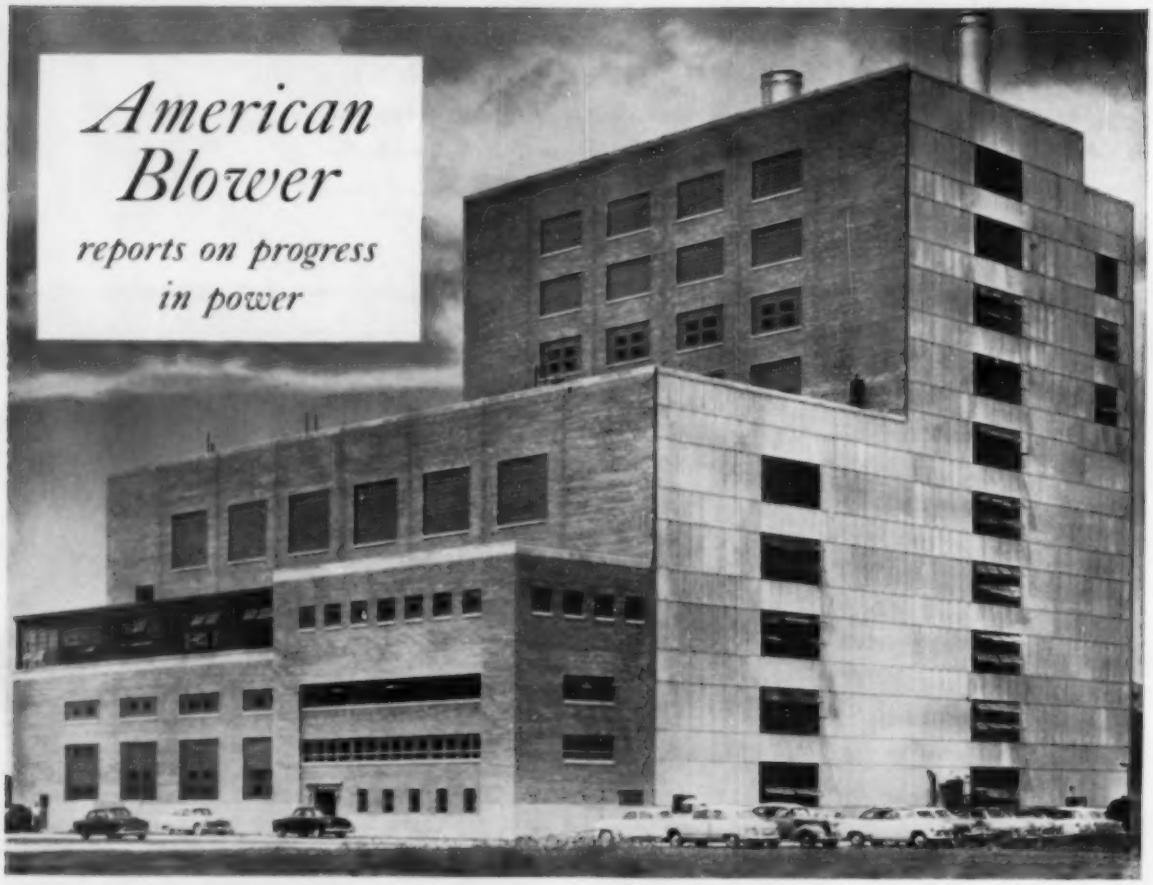
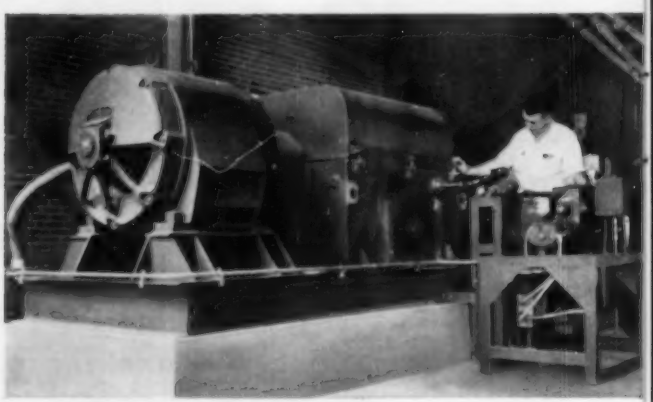
Iowa Electric Light & Power's kw



Iowa Electric's new Sutherland Station, under construction at Marshalltown, will have two generating units. First unit, with 33,000 kw capacity, was completed in 1955.

American Blower Induced Draft Fans on Sutherland Station's new No. 1 unit are rated @ 97,000 cfm @ 356° F @ 11.75" sp @ 239.0 bhp.



Driving induced draft fan, American Blower Gyrol Fluid Drive – class IV, type VS – provides adjustable speed control; is rated @ 250 hp @ 870 rpm.

sales increase 356% in 17 years!

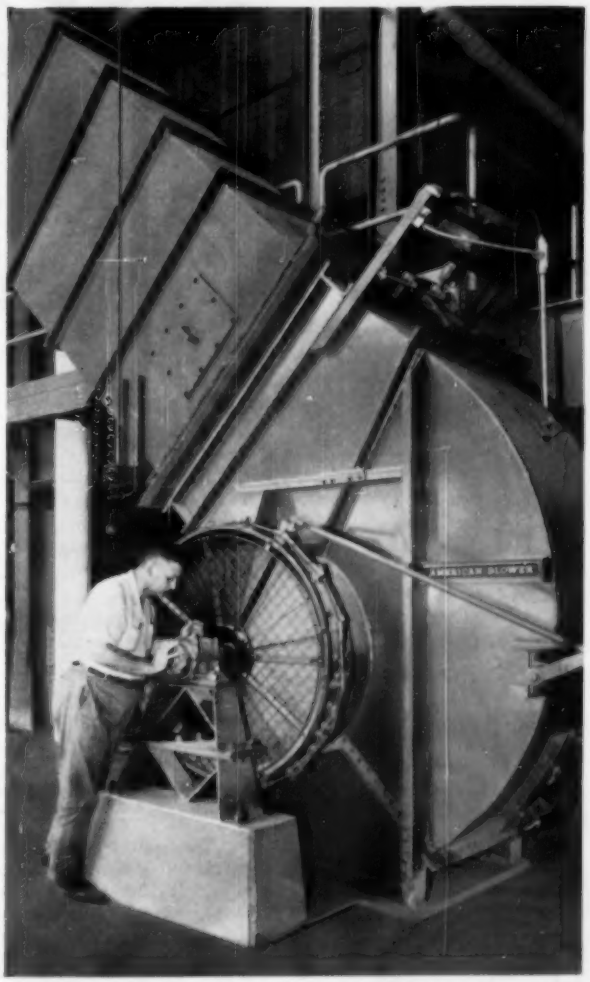
Relying on experience, rapidly expanding utility chooses American Blower air-handling equipment

1936 ushered in a phenomenal growth period for the Iowa Electric Light and Power Company. Fast-rising electrical needs called for new and larger facilities, longer distribution lines. Two mergers extended the company's operations. By 1953, 17 years later, Iowa Electric was serving 51 counties – and kilowatt-hour sales were up 356%! Today, Iowa Electric's facilities are still mushrooming. And the end is nowhere in sight!

Expansion has included new electrical generating units at the Boone and Cedar Rapids Plants . . . where American Blower Forced and Induced Draft Fans, Gyrol Fluid Drives, and a Fly Ash Precipitator were installed. This equipment has proved so dependable and free of maintenance that Iowa Electric again chose American Blower for Sutherland Station, its new plant at Marshalltown, completed in 1955 (first of two units to be constructed).

Experience has led many other progressive, investor-owned utilities to specify American Blower again and again, when expanding or modernizing. "There's no substitute," they report, "for the quality of American Blower Mechanical Draft Fans, Fly Ash Precipitators, Heavy-Duty Steam Coils, and Gyrol Fluid Drives for boiler feed pump and fan control." They rely on American Blower . . . you can too.

American Blower branch offices are conveniently located throughout the U.S. You'll find one of our representatives easy to contact – to discuss *your* problems.



No. 1 unit at Sutherland Station uses American Blower Forced Draft Fans, each with 57,500 cfm capacity @ 120° F @ 11.6" sp @ 138.0 bhp.

AMERICAN BLOWER CORPORATION
DETROIT 32, MICHIGAN

CANADIAN SIROCCO COMPANY, LTD.
WINDSOR, ONTARIO

Division of American Radiator & Standard Sanitary Corporation

AMERICAN BLOWER

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In the costly processes of today's industry — where fluids are confined in searing heat and brutal pressures — taking a gasket for granted is serious business. The price of gasket failure is measured in damaged equipment, plant "down-time", danger to personnel.

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Editorials

Operations Research

A number of widely separated reports on the subject of industrial research occurring over a span of months have brought to mind the rather sharp change research programs have undergone in this country in the last decade. Most of us know or are aware of the increase in moneys allotted by general industry to research activities. The fact that World War II and the dislocations it produced cut us oft from much of the traditional fundamental research programs of the European continent contributed very largely to general industry's awareness of a need for much more of such work in the U. S. A. Along with the increased expenditures greater attention was paid to the different research techniques.

The fruits of this closer attention to techniques are already in evidence. The atomic Manhattan Project of World War II as R. C. Stevenson, president of Allis-Chalmers Mfg. Co., pointed out to the golden anniversary tractor meeting of the Society of Automotive Engineers, represented for the first time a move directly into mass production without benefit of a prototype. The engineers and scientists on the project were sure, two billions of dollars worth, and they proved they were right.

This concept is now being applied to the power development of atomic energy. The sound calculations and the expert laboratory techniques of modern day research permit industry to skip the trial and error stage of yesteryear. Electronic computation has become one of the most powerful of research tools. With it problems can be solved on paper that formerly had to be worked out on experimental models. Increasing use of applied math and computation which combine to make experimentation a paper operation is not only cheaper and faster but in the words of H. R. Grosch, manager, General Electric Co.'s aircraft gas turbine division, makes possible the exploration of many possible designs so that the final design selection stands much more chance of being the correct one.

Comments such as these from men as well placed as they are can give added hope to those who wonder where do we go from here. History shows that each time man comes up against the limitations of his father's time certain advances that bear out the old adage "Necessity is the mother of Invention" come to his aid.

What part can the average man play in research? The most important as we see it is to maintain the economic and politically-free climate that we as a nation have enjoyed. Within its atmosphere it truly seems that anything is possible.

The Atom and the Trade Fair

To engineers well abreast of current developments, trade fairs are sometimes of dubious value. This is more the case in long-established technical specialties where change is slow and evolutionary in character than in fields undergoing intensive development and rapid technological change. Certainly peaceful applications of atomic energy fall into the latter class, and those involved in promoting expositions have sensed the keen interest in nuclear activities. Almost every trade show in the engineering field now includes some exhibits concerned with the peacetime uses of atomic energy.

Starting with the United Nations Conference on the Peaceful Uses of Atomic Energy held in Geneva, Switzerland, in early August, the cavalcade of atomic trade fairs moved on to Washington, D. C., where the Atomic Industrial Forum sponsored the first U. S. Trade Fair of the Atomic Industry. Some 75 industrial firms and organizations participated in this show which Admiral Lewis Strauss, Chairman of the U. S. Atomic Energy Commission, described as an impressive exposition which he wished might be viewed by every American. He added, "It illustrates the vision, ingenuity and determination of private enterprise to advance the nuclear art. It is a timely and important sequel to the First Atomic Energy Conference in Geneva."

Those who missed the Geneva and Washington Trade Fairs have at least two opportunities forthcoming. To emphasize the interest of The American Society of Mechanical Engineers in the nuclear engineering field, the Chicago Exposition of Power and Mechanical Engineering will include an Atomic Power Section. This will be held simultaneously with the ASME Diamond Jubilee Meeting at the Coliseum in Chicago on November 14–18. Following this, in connection with the first national Nuclear Engineering and Science Congress under the auspices of the Engineers Joint Council, the American Institute of Chemical Engineers will sponsor an Atomic Exposition at the Public Auditorium in Cleveland, Ohio, from December 10 through December 16. According to B. F. Dodge, president of the AIChE, the exposition will bring together major developments in atomic power and in the tremendously expanding applications of atomic byproducts in many industrial fields.

Interest in atomic matters is currently at a high peak. To learn at first hand why this enthusiasm exists, and to become infected with the healthy disease of *nucleitis*, a visit to the forthcoming atomic trade fairs is hereby prescribed.

Integrated Steam Station Protection*

By Working Group on Steam Station Protection, Committee on Power Generation, American Institute of Electrical Engineers†

In light of the current interest in overall plant protection, this paper describes the problems in this complex subject and the activities which a working group is undertaking to resolve the many issues. It is hoped that other engineers and committees will be encouraged to contribute to the many specialized fields that the subject encompasses.

TO convert fuel to electrical energy in the most economical manner, the various elements within the steam power plant (boiler, turbine, generator and auxiliaries) must take advantage of the latest technological advances in the fields of metallurgy, chemistry, electricity and mechanics. Within the last few years considerable discussion has been offered on these developments as they affect separately the various elements within a steam power plant and enable the trend to larger units and more advanced thermal cycles to continue. However, with the advent of these larger boilers, turbines, and generators has come the philosophy of unit connection and centralized control wherein each machine and its accessories is treated as an entity. All of the elements in the plant from the coal yard right up to the high voltage switchyard affect the production of a particular steam plant. With this vast area under the surveillance of only a few operators, it is felt that the combined protection and interlocking of each element within the plant which provides overall plant protection should be given close scrutiny and considerable study.

In modern unit-connected plants, an error, not properly cleared, could jeopardize a large amount of expensive equipment or delay restoration of considerable output. This requires that a pre-determined sequence of starting and stopping each unit be followed and that protective devices and interlocks be provided to assure satisfactory and safe performance under normal as well as emergency conditions. The system and plant operating practices and protection schemes must be considered and the whole integrated into a common framework. Since many of the protective devices and interlocks are electrical in nature, the job of interlocking various devices to provide automatic steam station protection usually falls upon the electrical engineer.

For these reasons, the AIEE Committee on Power Generation has formed a Working Group on Steam Station Protection to investigate current protective schemes used within electric utility steam stations. This working group was charged with the responsibility of investigating interlocks from the viewpoint of protecting equipment, limiting travel, interlocking operations to orderly procedures and the protection of areas and personnel. These interlocks were to be investigated as applied by the engineer throughout the steam station. They may be in the form of limit switches; protective, auxiliary and timing relays; supervising instruments and even mechanical linkages. The reasons for use of unusual protective devices and interlocking schemes were also to be investigated.

This subject of steam plant protection is extensive and complex and yet, to date, few of the philosophies behind present practices have been thoroughly examined. Like any control scheme, the protection within the plant is subject to the personalities of those working on that particular scheme, to past practices, and to existing devices. Therefore, it was felt that a service could be rendered to the members of the Institute if this working group could approach and analyze the current protective schemes used in steam plants so that the basic philosophies beneath various plant protection schemes could be summarized in a report. This would enable the electrical control designer to obtain the necessary overall picture so that he could recognize the importance of each situation. At the same time, it is hoped such a report could eliminate much of the complication presently found. It should also facilitate the training of new designers and operators by placing in writing the need and manner of protecting the steam power plant.

Outline of Problem

As pointed out previously, the scope that such a report would undertake involves the boiler, turbine-generator and associated equipment. In order to cover such a broad problem, the group proposes to segregate the equipment in the steam power plant into five general categories. The protection and interlocks provided for the equipment that fall under each category would be investigated and thus, some order would be present in the requests for information and in the final presentation. It is suggested that all of the elements would be combined into an overall protective system by depicting their location and function on a single one-line diagram. The following outline is not the form in which the questionnaire shall appear, but it does suggest the procedure that the working group believes should be followed in attacking the problem.

I. BOILER

A. Furnace (either suction or pressure)

* Presented at AIEE Fall General Meeting, Chicago, Ill., Oct. 3-7, 1955.

† Personnel serving on the Working Group is as follows: R. M. Sauter (Westinghouse Electric Corp.), Chairman; H. C. Barnes (American Gas & Electric Co.), J. L. Holton (Consolidated Edison Co. of New York), A. H. Mergenthaler (Southern Services, Inc.), A. G. Mellor (General Electric Co.), C. F. Paulus (Cleveland Electric Illuminating Co.).

1. Air
   a. Supplied by ID and FD fans if on suction or FD only if on pressure.
      i. Interlocked for starting and stopping sequence.
      ii. Protective interlocks provided for loss of one or more fans and in what combinations.
      iii. Alarms provided.
   b. Purging controls.
      i. Purge assurance interlocks for control of furnace draft conditions.
      ii. Alarms provided.
   c. Air heater controls.
      i. Interlocks provided.
      ii. Alarms provided.
   d. Furnace or flue pressure controls.
      i. Interlocks provided for excessive pressures.
      ii. Alarms provided.
2. Fuel
   a. Type of fuel and fuel handling equipment (divide protections according to coal, oil or gas).
      i. Interlocks provided to prevent starting fuel flow or trip fuel flow during weak draft and other undesirable conditions, i.e., fan failure, turbine stop or control valves closed, insufficient boiler controlled-circulating-pump differential pressure, etc.
      ii. Interlocks for protection against loss or interruption of fuel.
      iii. Alarms provided.
3. Ignition
   a. Sequential and protective interlocking installed for oil lighters.
   b. Sequential and protective interlocking to assure gas combustion.
   c. Alarms for loss of ignition supply voltage.
4. Residue Removal
   a. Ash and gas removal.
      i. Fly ash and stack gas controls (electrostatic precipitator).
      ii. Furnace bottom ash including ash grinder and ash pump controls.
      iii. Electrically operated soot blower controls.

B. Steam Generator
1. Water Cycle
   a. Interlocks provided.
      i. Interlocks and alarms provided for assurance of differential pressure for controlled circulation cycles.
      ii. Interlocks and alarms provided for non-controlled circulation cycles.
      iii. Alarms provided.
   b. Supervisory instruments and protective devices.
      i. Makeup.
      ii. Purification (include controls and alarms for demineralizer system).
      iii. Low and high pressure heaters and boiler drum level indications.
      iv. Alarms provided.
2. Steam Cycle
   a. Pressure protection.
      i. Below critical pressure.
      ii. Above critical pressure.
   b. Temperature protection.
      i. Reheater.
      ii. Superheater (include desuperheating controls).
      iii. Attemperators.

II. TURBINE

A. Steam Control
1. Throttle or Main Stop Valves
   a. Associated tripping controls.
      i. Tripping conditions and sequence.
      ii. Interlocks operated by throttle valves.
2. Governing Devices
   a. Speed governing valves for speed control and associated interlocks.
      i. Main governor.
      ii. Emergency or overspeed governor.
      iii. Overspeed lockout.
      iv. Pre-emergency governor (intercept valves).
   b. Load limit device.
3. Reheat Valves
   a. Associated interlocks for intercept and reheat stop valves.
      i. Tripping conditions and sequence.
4. Exhaust Controls
   a. Bleeding.
   b. Vacuum.
      i. Interlocks provided for condenser, turbine and associated equipment.

B. Oil System
1. Lubrication
   a. Electrically-driven oil pump control and associated interlocking between a-c and d-c pumps to prevent loss of oil pressure.
   b. Action, if any, derived from bearing oil temperature and bearing temperature.
   c. Low bearing oil pressure interlocks or alarms.
2. Control Oil

C. Miscellaneous
1. Temperature
   a. With turbine driven by generator.
      i. Blade temperature.
      ii. Shell temperature.
2. Shell and Differential Expansion
3. Vibration
4. Turning Gear Motor Control and Associated Interlocks
5. Turning Gear Oil Pump Control and Associated Interlocks

III. GENERATOR

A. Fault Detection
   1. Protective Devices for Stator Windings
      a. List of equipment to detect balanced and unbalanced faults up to and including the generator breaker whether it exists at generator voltage or transmission line voltage.
      b. Interlocks provided.
   2. Protective Devices for Rotor Windings
      a. Equipment for short or open circuit in rotor winding, and grounds or opens in excitation circuit.
      b. Interlocks and alarms provided.
   3. Protective Devices for Machine Safety
      a. Functions provided for following conditions: excessive current in stator or rotor windings, reverse power flow, unbalanced current operation, out-of-step operation, loss-of-field, excessive temperatures, excessive vibration, failure of bearing insulation, fire.

B. Cooling and Temperature Controls
   1. Stator
      a. Conventional hydrogen cooled.
      b. Contact-cooled.
         i. Hydrogen.
         ii. Liquid.
   2. Rotor
   3. Hydrogen
      a. Temperature.
         i. Water flow control under normal and emergency conditions.
      b. Purity.

IV. AUXILIARY SYSTEM

A. Power Supply
   1. Fault Protection at Various Voltage Levels.
      a. Interlocks and protection provided.
   2. Bus Transfer.
      A. Normal transfer.
         i. Open or closed circuit.
         ii. Determination of equipment transferred.
      b. Emergency transfer.
         i. Determination of equipment to transfer under varying conditions.

V. PROTECTION OF PERSONNEL

A. Mechanical and Electrical Interlocks to Assure Safe Maintenance, Inspection and Operation of Plant Equipment

An attempt by the working group to establish a questionnaire that would supply the information necessary to fill in the above outline is currently under way. As evidenced by the outline, boiler protection does not require many electrical circuits since it is accomplished by mechanical means. However, the protection of the boiler must be coordinated with that of the turbine and the electrical end of the machine so that troubles anywhere in the plant will cause complete or partial shutdown of the entire unit as may be demanded by the type of failure involved. With these important features in mind, the working group is interested in determining the elements, their position and priority in the over-all protective system as applied to the latest steam units of the various utilities in the United States. Recently, information of this nature has been appearing in various technical papers[1,2,3] and we would be interested in determining the extent to which other utilities have undertaken the problem of placing on one sheet the overall protection of their steam plant.

Concomitant with this discussion of the extent and nature of steam plant protection, there arise many questions on which the working group would be interested in having diverse opinions. Some of these are:

1. Is there a better procedure for determining current plant protection practice among AIEE members other than a detailed questionnaire?
2. Does the outline presented by the working group appear lucid, logical, and complete?
3. Should the questionnaire cover only a particular machine or request the practice which would be followed on new installations?
4. If a particular machine is chosen, should it have a minimum size, for example, 100 MW?
5. Is there a correlation between the number of operators per unit and the extent and development of overall plant protection scheme?

In an attempt to obtain general information on a particular installation, some of the questions which were proposed by the working group are given in Appendix I. It is expected that shortly a complete list of questions dealing with boiler protection will be completed and then other segments of the outline will be expanded into detailed questionnaires.

Summary

From the broad scope of this working group, it is realized that the boundaries of several existing committees and subcommittees are being crossed. This condition always exists when obtaining an overall picture. Great assistance would be afforded the group if the committees interested in various phases would make available the pertinent information they possess on a particular phase of plant protection. It is with these desires of eliciting help and information from other sources within AIEE that this paper was presented. It is hoped that it has accomplished this task.

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APPENDIX I

PROPOSED GENERAL INFORMATION QUESTIONS

Name of Company
Location of Station

Last Commissioned Unit

Date of Commissioning
Capacity
Steam Pressure
Steam Temperature—Original
Reheat
Fuel
- Gas
- Oil
- Coal
  - Stoker
  - Cyclone
  - Pulverized
    - No. of Mills
    - Type of Mills

Ignition
- Gas
- Oil

Furnace Pressure
- Negative
- Positive
- No. of Fans
- Fan Drives
  - Turbine
  - Motor
    - Vane Control
    - Fluid Drive

Boiler Feed Pump Drive
- Motor
- Turbine

Soot Blowers
- Type

Combustion Control
- Type

Air Heater
- Type

Fly Ash Collector
- Mechanical
- Electrostatic

Bottom Ash
- Dry
- Slag

Control Room
- Combination
- Boiler Only

Auxiliary Power Supply
- Normal
- Start-Up

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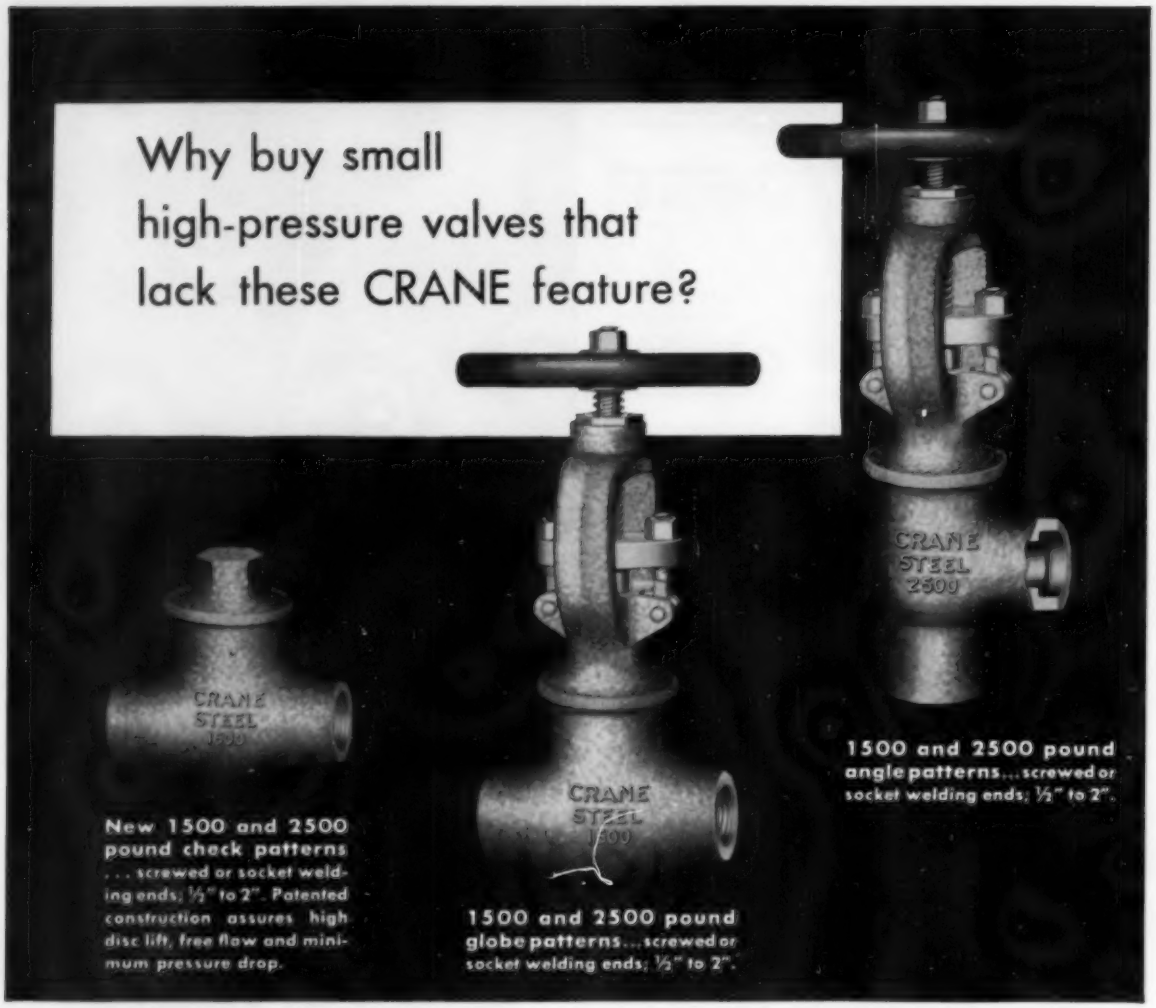

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- stems that do not bind or gall — because of CRANE's exclusive ball-joint glands;
- easy access to stuffing box — swing-type gland eye-bolts swing free of yoke area, can't be lost;
- a more rigid swivel disc-stem connection that minimizes vibration;
- each size valve is a separate design for proper proportion — another CRANE exclusive.

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Fig. 1—New Nantes-Cheviré Station of the Electricite de France will have an ultimate capacity of 500,000 kw when the last unit goes in. There is 200,000 kw as of now.

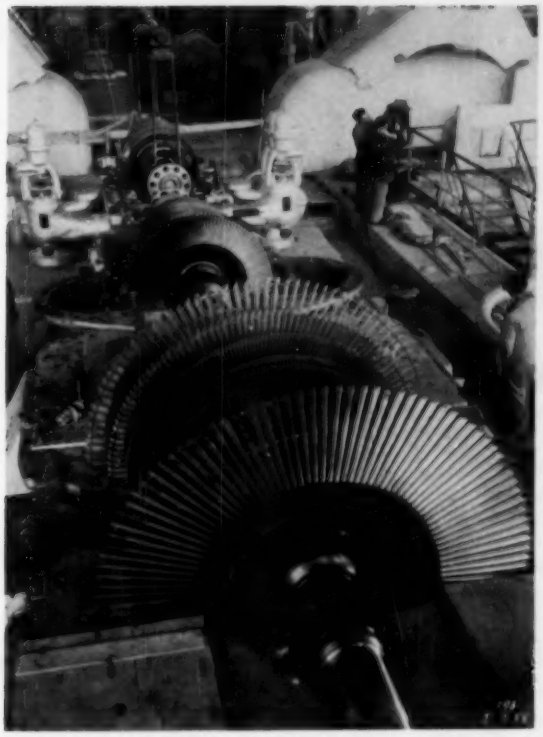


Fig. 2—One of the turbines for the station is shown in the course of its assembly. Two 50,000-kw units and one 100,000-kw machine make up the present capacity

Nantes-Cheviré Station

Between 1920 and 1930 France experienced a load growth rate greater than any other country in the world but World War II damages upset this growth rate. However, the years 1944 to 1950 have seen the load expanded 88.5 per cent as a result of rehabilitation. This article describes a very valuable addition to the country's power capacity.

By G. F. BRINER
Gilbert Associates, Inc.

PRIOR to 1948, Western France was exceedingly underdeveloped in the production of electric light and power. The City of Nantes in Western France, situated as it is in a large industrial area, was a logical choice for locating a new central power station. As a result the Nantes-Cheviré Station of Électricité de France was established at a site approximately 35 miles east of St. Nazaire along the Loire River.

Construction of the first stage consisted of the installation of two units of 50,000 kw each and was begun in 1950. The first two units were placed in commercial operation by the latter part of 1953. The second stage, a 100,000-kw unit, was started in 1951 and will be placed in operation during 1955. The third stage, consisting of one 115,000-kw unit, has been started this year and completion is anticipated during 1958. The total station output will ultimately be approximately 500,000 kw.

Plant Site

"L'Ile Cheviré," the plant site chosen by Électricité de France, along the South bank of the Loire River, west of Nantes, was relatively low and was not used industrially before this time because it was frequently flooded at high tide by the Loire River. Before any construction began, therefore, the land was filled into a height of four meters over an area of approximately 130 acres with sand taken from the Loire River.

Since the area around l'Ile Cheviré had no means of access, it was necessary to establish a railroad route to the plant site. The route, connecting to the system of

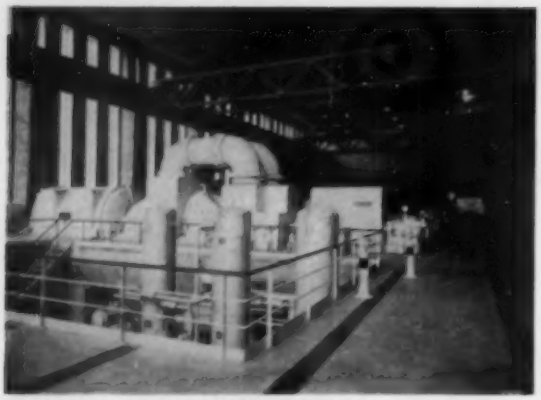


Fig. 3—Turbine room consists of five bays, measures about 125 ft. in width and has two 100-ton overhead cranes

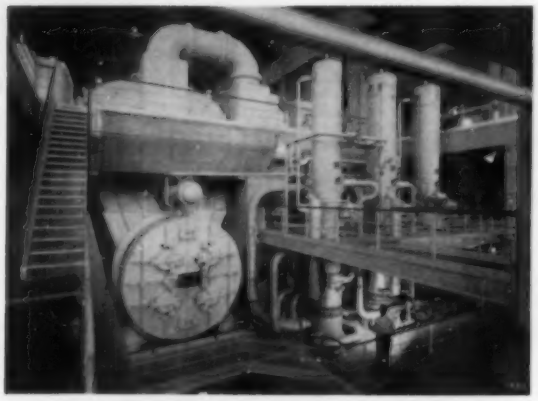


Fig. 4—Condenser and pump room level shows one of the units which requires 48,500 gpm of river water for condensing

Société Nationale des Chemins de Fer, entailed considerable embankment work. Further it was necessary that the railbed be constructed so it would be capable of withstanding heavy loads. The siding extends four kilometers from the Pont-Rousseau Station. (See cover photo for more detail of the area surrounding the power plant.)

At the same time that electrical power was extended to the plant site from the old station at Chantenay connecting to the French electrical network, city water and gas were led to the station site through two water and two gas lines laid across the Loire. The launching and submerging of these pipelines was the most unusual operation that took place during construction of the Station. The lines were designed in the shape of an elongated "U," each having a total length of more than 300 meters (934 feet). The piping was assembled on a launching ramp and slipped into place in a trench dredged across the Loire. The design and installation of these pipelines were performed by Ponts & Chaussées, Maritime Service of the Lower Loire.

The first task undertaken in the construction phase of the power plant was a series of borings to determine the best location for the building on the plant site. About sixty borings were made over an area of more than 600,000 square meters. Most of the borings were confined to the vicinity of the main building. These borings established that two rock projections existed in the subsoil at slightly different elevations. The projections were separated by a valley connecting the rocky ground of the present bed of the Loire River with the south channel. Apparently this valley must have formerly constituted a branch of the Loire and was filled in by sedimentary deposits. In this valley the borings revealed deep beds of slimy and muddy clay which probably were deposited because of weak currents existing in this connecting channel. The beds of clay in the borings were lenticular except on the sides of the river bed which were filled with sand.

The rock found in these borings was a granulated, highly crystalline variety having a brittle superficial crust of variable thickness. Since the sand interspersed with clay could not be considered as acceptable foundation soil, the building foundations were extended down to rock and the service wing of the building was constructed on piers extending to the rock bed. To maintain the depth of foundations at a minimum, the buildings were located on the highest rock projections.

Station

The boilers of this station are designed to burn pulverized coal or fuel oil. Normally, the fuel oil is brought in by barge from the Donges Refineries located about 40 km (25 miles) from the station and is stored in two (2) 20,000 m^3 (4,770,000 gallon) storage tanks.

The main buildings consist essentially of the boiler room, turbine room and pump room.

For the first two installations, the boiler room contains four (4) Combustion Engineering Company design boilers. Number one boiler was fabricated almost entirely in the United States and erected by Combustion. Number two boiler drums, superheater, economizer and some miscellaneous accessories were fabricated in the United States and the balance of the materials was furnished by Stein & Roubaix and Penhoët. Numbers three and four boilers of the second installation were fabricated and erected by Stein & Roubaix. The four boilers of the first and second installations have the same rating. Each boiler is rated at 227 tons (500,535 lbs) per hour at 93 kg/cm^2 (1322 psig) and 530 C (986 F).

The steam demand at normal operation is 418,950 lbs/hr. The combustion rate is 14,612 $Btu/ft^3/hr$ and the heat liberation per square foot of projected water wall surface is 73,651 $Btu/ft^2/hr$.

By dimensioning the boiler liberally, as indicated by the relatively low combustion and heat liberation rates for firing Lorraine bituminous coal, the gas temperature at the boiler outlet is held to a maximum of 1904 F. These low rates prevent slag from adhering to the water wall tubes and superheaters. The ash softening temperature is 2012 F.

The boiler room roof extends approximately 50 m (164 feet) above the embanked land which makes this the highest building in Western France. The steel stacks extend 26.5 m (87 feet) above the roof.

For the first two installations the turbine room contains two (2) 50,000/55,000 kw and one (1) 100,000/110,000 kw hydrogen-cooled turbine-generators. Unit No. 1 consists of a Brown Boveri Company turbine and a Compagnie Électro-Mécanique generator. Unit No. 2 was fabricated entirely by Compagnie Électro-Mécanique.

Fig. 5—Central control room carries enough automatic devices to reduce operating personnel to a 7-man shift

Fig. 6—Large windows in central control room face both the turbine and boiler room so operators can see both

Unit No. 3 turbine was constructed by Rateau and the generator by Jeumont. The three units are rated at 89 kg/cm² (1266 psig) and 520 C (968 F). The condensers serving the turbines were fabricated by Delas.

The turbine room is composed of five (5)11. 5 m (37.7 ft.) bays and the width is about 38 m (125 feet). It is equipped with two (2) 100-ton traveling cranes for handling the turbine and generator parts.

The pump room houses the motor-driven circulating water pumps fabricated by Bergeron and driven through Citroen speed reducers. Approximately 11,000 m³/hr (48,500 gpm) for each 50,000-kw unit and 19,500 m³/hr (85,700 gpm) of Loire River water are required for the first and second installations, respectively. The cooling water for the condensers passes through Beaudrey-Bergeron rotating screens.

Since the Loire is a navigable river, provisions were made for receiving both coal barges and fuel oil ships. A continuous pier extending 135 m was constructed along the Loire.

The service section of the central station provides a machine shop, warehouse, shower and locker rooms, infirmary, offices, garages, etc.

Extensive studies were performed to determine the best station heat rates. It was determined that a total of six turbine extraction stages should be used to heat the condensate leaving the condenser from 77 F to a feedwater temperature of 446 F at the boiler inlet. Three (3) low-pressure and three (3) high-pressure extraction feedwater heaters were installed. The gross station heat rate is 11,100 Btu/kw/hr. It is interesting to note that in the summary of heat rates for all French thermal stations during 1953 the average gross station heat rate was 16,000 Btu/kw/hr.

The boiler feed pumps furnished by Sulzer are driven by 1750-hp constant speed electric motors at 3,000 rpm through hydraulic couplings.

The induced and forced draft fans operate on a common spindle and can be driven at three different speeds. The fans are driven by one 1080 hp constant speed motor at 750 rpm or one 720-hp two-speed motor operating at 400 rpm and 600 rpm. Combustion air and exhaust gas regulation are controlled by dampers. These damper controls are part of the Bailey automatic combustion control system installed in the station.

The generator voltage is 10,500 volts. This voltage is stepped up by power transformers to 60,000 volts for the local system and 150,000 or 220,000 volts for the interconnecting transmission system of France.

The electric motor drives whose ratings range between 150 and 1750 hp are supplied from 5,000 volt switchgear. Motors having a rating below 150 hp are supplied from switchgear at voltages of 380, 220, 110 and 24 volts.

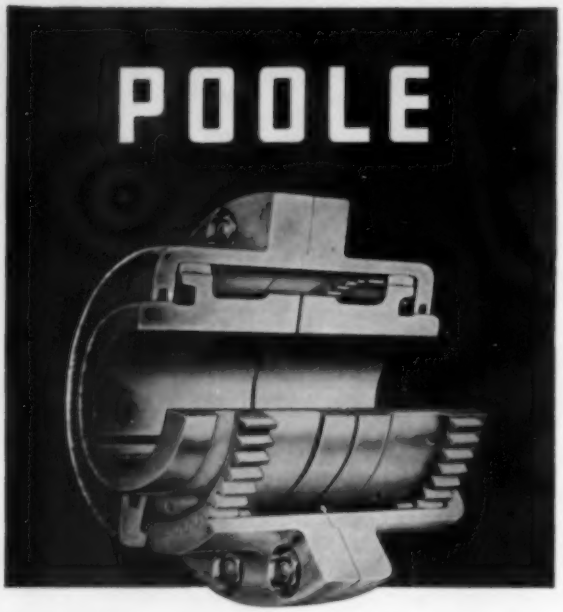
One of the prime objectives in the layout of the station was to reduce the number of station personnel to compare closely to that in American power stations. In order to accomplish this, the station is arranged to include a central control room located midway between the boiler and turbine rooms. The boiler and turbine control panels are equipped with sufficient automatic devices to reduce the number of operators throughout the station to a skeleton crew. The automatic devices installed include the following:

1. Boiler feed pump control.
2. Combustion control.
3. Controls for electrostatic dust collector.
4. Turbine supervisory instruments.
5. Soot blower sequential control system.
6. Sequential control system for evacuating fly ash.
7. Steam temperature control system.
8. Utiliscope for viewing furnace interior.

The central control room is insulated for heat and noise and is equipped with large windows facing both the boiler and turbine rooms. Many of the manual and automatic controls have been extended to the operating floor level to be readily accessible to station personnel.

A total of five (5) groups of seven men each are sufficient to operate the first two 50,000-kw units. Including supplementary services such as coal handling, ash handling and maintenance crews, the total personnel required is 80 men. As future installations are added, the supplementary crews will not have to be increased appreciably. It is interesting to note that during 1953 the French power stations averaged 300 men for every 100,000 kw.

The structural members of the station were constructed entirely of reinforced concrete with the exception of the turbine room roof. The substructures subjected to the higher loads, particularly the supports for the operating floor and the turbine-generator foundation, were poured



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with a concrete pump. The superstructure was poured either with a concrete pump or with the aid of cranes.

The materials required for the first and second installations include: 50,000 cubic meters of concrete, 95,000 square meters of siding and 7,500 tons of steel.

The cement was transported by the railroads, the aggregate came from a neighboring quarry and the sand came from the Loire River. The mixture of the concrete was controlled automatically or semi-automatically. A yard laboratory permanently established during construction controlled the quality of the concrete mixture.

The architectural styling was accomplished by using aluminum panels attached to a steel frame that was fastened to the building concrete structures. For the building interior this steel frame also supports Monorélith panels. These panels have a smooth surface and do not require any protective coating. The air gap between the aluminum panels and the Monorélith panels is 60 cm (approximately 23.5 inches) and forms an excellent thermal insulation for the building. The turbine room contains a number of large windows that provide the building interior with natural light.

The City of Beauvoir

Not very far from the Nantes-Chevire Station Électricité de France erected a community for the station personnel during construction of the station. The property purchased was formerly the estate of Beauvoir Castle. Actually this building is not a castle but a comfortable house characteristic of the latter part of the Nineteenth Century. The land is conveniently situated along the side of a hill, southwest of the Station. The homes that have been constructed are surrounded by large trees and the prevailing winds carry the exhaust from the station chimneys in the opposite direction. The City of Beauvoir at the present time provides living quarters for sufficient personnel to operate the station at 200,000-kw capacity. The homes consist of: 8 three-room buildings, 20 four-room buildings and 4 five-room buildings. A wood storeroom adjacent to each home provides space for the family bicycle. The presence of hardrock did not permit the excavation of basements under the homes.

Between 1920 and 1930 the electrical system in France experienced a load growth rate greater than any other country in the world. However, the load growth suffered a very serious setback as a result of World War II damages. In the postwar six-year period between 1944 and 1950, the load expanded 88.5 per cent as a result of rehabilitation of facilities indicating a large demand for power.

The Nantes-Chevire Station is a representative milestone in meeting the power demands of the ever-increasing industrial development in France.

Potomac Electric Power Company has retained **Stone & Webster Engineering Corporation** to design and construct a 100,000 kw extension to the Potomac River Generating Station in Alexandria, Virginia, to augment the existing power supply to the District of Columbia.

In both June and July, all previous records for electric power consumption were broken by Potomac Electric Power Company which reports that the area served by it is growing so fast that its power demand reached 811,000 kw in midsummer.

Atomization of Liquid Fuels by High Pressure Natural Gas*

To improve flame effectiveness in open hearth steel making studies were made of flame patterns of oil and gas burners and the influence exerted upon them by the inner cone with particular emphasis on the role of the atomizing agents—air, steam and natural gas—the last of which produced particularly good results.

By George Grosvenor†
Colorado Fuel and Iron Corp.

THE use of high pressure gas at Colorado Fuel and Iron Corp. has been a development which has taken place in a series of steps since 1949 when a member of the firm's combustion department, Eugene Miller, was assigned to the open hearth for this development work.

It was recognized that flame temperature is not necessarily, by itself, a criterion of the effectiveness of a fuel for a particular work. The effectiveness of a flame is not altogether measured by temperature but by the intensity of combustion. In the case of an open hearth flame, it is the brilliance of the incandescence which is produced in the split second transitional period in the reaction when the free carbon is released from the heavy fuels reaching its maximum incandescence before combining with the O_2 present.

Flame Pattern Studies

Mr. Miller's work was centered on the importance of the removal of the inner cone and its controlling effect on the rate of flame speed. In this development, the inner cone has been partially eliminated and substituted in its place is a sharply defined area of maximum flame heat.

When the kinetic energy of the fuel input is derived almost entirely from the use of steam, one can readily perceive why the elimination of steam from the flame area is a desirable development. In the flame itself, the reaction processes are profoundly affected by the presence of the steam.

In short, what occurs is this, the four, five, or six pounds of steam per gallon of oil which is introduced with fuel, being in the flame area, goes through the process of dissociation into its component parts. This process of dissociation absorbs a tremendous amount of energy and in an area where it will materially reduce the intensity of the flame. An equal amount of energy is given up as the reassociation of the elements takes place but unfortunately takes place where the least amount of benefit can be derived.

The first burner developed at Colorado Fuel and Iron Corp. in 1949 was constructed for premixing natural gas and air or oxygen before entering the furnace. This was accomplished by the utilization of cold primary air induced through the use of a patented venturi mixing chamber with the fuel oil being atomized with steam. This burner was used on No. 7 furnace in 1950 and a monthly record was attained, using seventy per cent of the total Btu input from natural gas, at an ingot cost saving of twenty cents per ton. This saving was primarily due to the difference in the cost of the two fuels.

Due to the shortage of natural gas through the winter months, it was necessary to develop a burner for liquid fuel only. This phase of the development led to the use of a double gun burner, using steam and compressed air as the atomizing agents. This proved very satisfactory and as natural gas became more plentiful, high pressure natural gas was used as an atomizing agent.

All preliminary work was done on small scale models and operated in the open which permitted a close study of flame patterns. The design of a full scale burner was based on the desired flame pattern of the small models.

The study procedure included the use of natural gas at pressures up to 150 psi with various sizes and shapes of nozzles. The oil and air combinations were studied in the same manner. This work was based upon the theories which would permit the maximum utilizations of the inherent kinetic energy to be gained from high pressures. The bottom section of the burner is essentially a venturi with an air port through the burner shell, opening inside the furnace, which permits the use of superheated air from the uptakes, as shown in Fig. 1. This resulted in a short flame of high temperature and radiation. The angle and shape of the nozzle block in the top gun projects the high pressure gas and fuel oil mixture through this area of maximum temperature where the high kinetic energy content causes very rapid mixing and produces a high rate of flame propagation of the entire fuel input giving a short compact flame of intense temperature and radiation.

Fig. 2 shows the nozzle block angle of the top gun.

After the preliminary and experimental work had been completed, and the desired flame pattern had been obtained, a full scale burner was built for furnace trial.

Burner Construction and Operation

Fig. 1 as shown and Figs. 3, 4 and 5 show the detail section of the burner for which patents have been applied by Mr. Miller.

* Reprinted by special permission from "Iron and Steel Engineer," October, 1954, pp. 77–80.
† Open Hearth Superintendent, Pueblo, Colo.

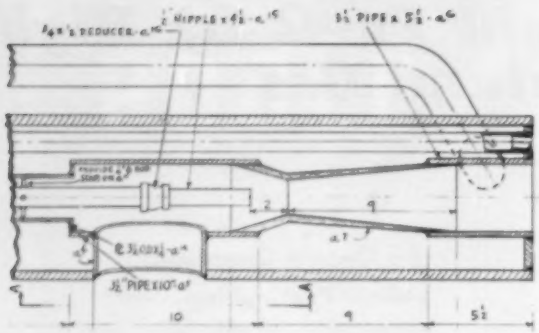


Fig. 1—Bottom section of the full-scale oil burner designed to employ natural gas as an atomizing agent. This section is essentially a venturi with an air port through the burner shell so heated air from the uptakes can be applied

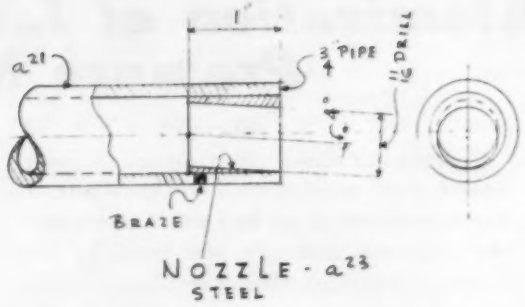


Fig. 2—Nozzle block angle of the top burner gun, 4 degrees, and nozzle shape, above, projects high-pressure gas and fuel oil mixture through the high temperature zone created by the bottom burner, Fig. 1

We found that most furnace crews approach the use of high-pressure gas with a great deal of timidity. For this reason considerable care was taken in the selection of a furnace crew for the trial period, and today, through an educational program, this fear of high-pressure gas has been effectively eliminated with most of the men.

After due consideration given furnace crews, the first burner was placed on No. 16 furnace in September 1952. It was so constructed that the fuel could be atomized with either steam, air, natural gas, or any combination of these atomizing agents. We have found that our best results have been obtained through the use of natural gas at 140 psi pressure in both top and bottom burners, but the temperatures are so high that extreme care must be taken during the shaping-up period of the heat to prevent burning the roof. Due to this condition, some of our furnacemen are changing from natural gas to steam for atomizing during this period on the bottom burner. In October the production on No. 16 furnace was increased from 9586 net tons to 10,373 net tons with the furnace being down during the month for a shot-gun or a quick roof. This was an increase of 787 net tons. In January of 1953 the monthly record was again raised to 11,073 net tons or an increase of another 700 net tons making a total increase of 1487 net tons. However, this increase cannot be contributed entirely to the use of high-pressure gas. Hot metal was increased in our charge from 46 to 56 per cent during the same period, but the only furnaces in which we have been able to produce 10,000 net tons or better, have been on the furnaces using high-pressure gas. During January 1953 on No. 16 furnace, we tapped 95 heats, with an average tap-to-tap time of 7 hours and 56 minutes, and a charge-to-tap time of 7 hours and 9 minutes and for one week during that month, we tapped 24 heats giving a rate of 404 net tons per furnace day, or 31.98 tons per hour per 1000 square feet of hearth area. Due to this performance on No. 16 furnace, we have just completed installing a new 10-in. high-pressure gas line throughout the shop.

Flame Temperature and Behavior

By the use of an optical pyrometer we are getting flame temperatures ranging from 3450 to 3600 F at the No. 1 and No. 2 door peep holes, with the flame tailing out at the No. 3 door and with a temperature of 3100 F at the No. 5 door. During this record performance, we tapped two 110-ton heats in 4 hours and 55 minutes and any number of five and six-hour heats with an average two-hour charging time. Our job today is to reduce our charging time of scrap if additional tonnage is to be made.

The flame pattern is shown in Figs. 6, 7, 8 and 9. Fig. 6 shows flame pattern with both top and bottom burners operating. Fig. 7 shows pattern of top burner only. Fig. 8 shows pattern of bottom burner only illus-

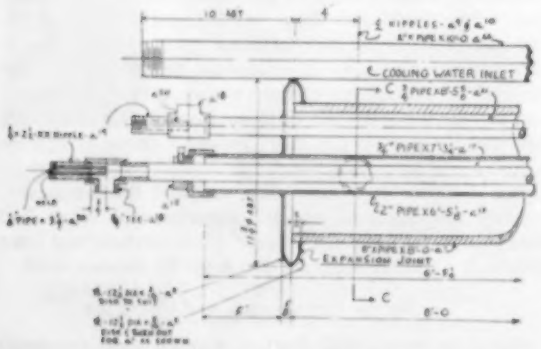


Fig. 3—Back end of the developmental burner gun assembly shows in the above sketch

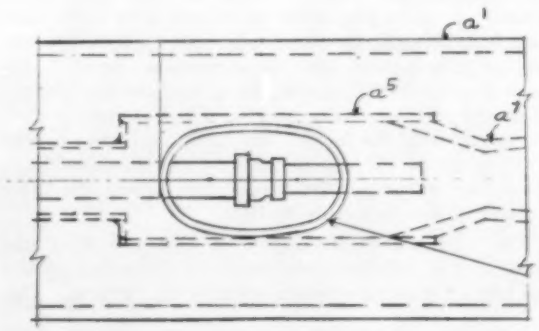


Fig. 4—The enlarged air port opening in the burner shell appearing at the bottom of Fig. 1 is drawn full view

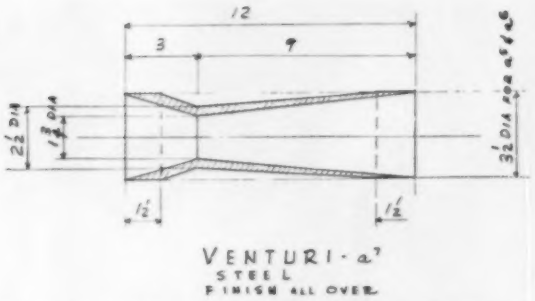


Fig. 5—Detailed data on the venturi employed in Fig. 1 is supplied in the sketch above

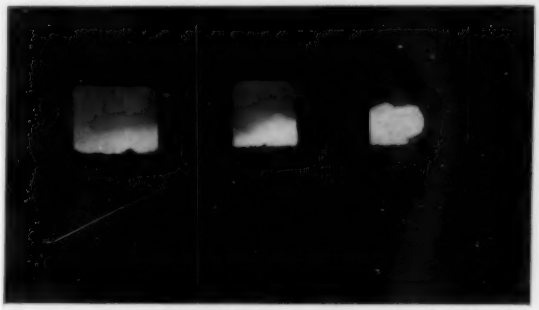


Fig. 6—Flame pattern with both top and bottom burners operating has been photographed as above

trating the rapid flame propagation and the area of maximum temperature. Fig. 9 shows the nose of the burner and the angle in which the high pressure gas and fuel oil is projected through this area of maximum temperature.

Experience has shown us that the use of high pressure gas in this manner has had no detrimental effects on roof life. Roof life actually has shown a 10 per cent increase on this furnace, but as most of you realize this can probably be contributed to the additional attention given to the furnaces.

The sensitivity of these burners and the extreme temperatures obtained makes it desirable to have close cooperation between the furnacemen and the fuel department personnel. Instrument setting of the furnace is very practical, in fact, a required practice in order to obtain the maximum operation from the furnace. This condition presented an opportunity to conduct an educational program on the use of this fuel. A class was held once a week with one melter and his group of first and second helpers. The program was set up to utilize the practical knowledge which these men have obtained through experience and the simple presentation of the technical background of the burner with the idea of placing them on their own initiative in determining the proper furnace setting and fuel usage to gain the greatest advantage from their individual furnaces.

This type burner is especially valuable in a shop with a high scrap charge. Scrap melt-down occurs at a remarkable rate, and thus much overall heat time can be saved. We have also noticed, that in many cases, half of the limestone is pulled by the time the ore flush is completed, and that the furnace is hot and ready to tap when the lime is up.

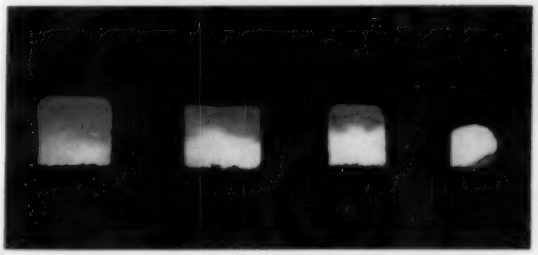


Fig. 7—When only the top burner is in operation the flame pattern becomes as shown here

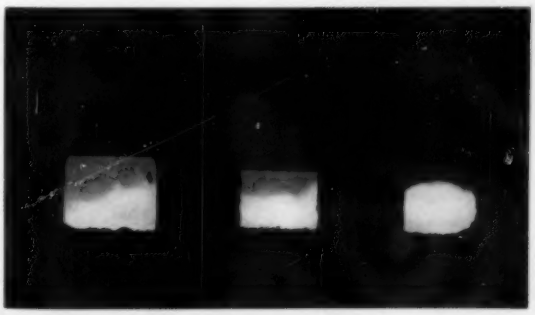
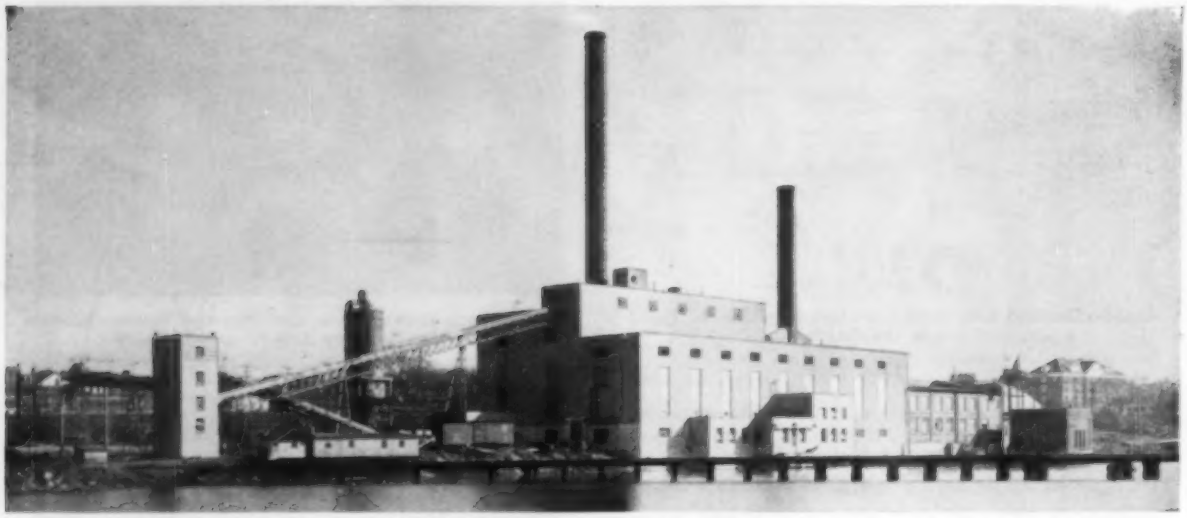


Fig. 8—Bottom burner, alone, results in the flame pattern here. Flame is short and of high temperature indicating a rapid flame propagation and a confined area of intense temperature

Experiences and Results

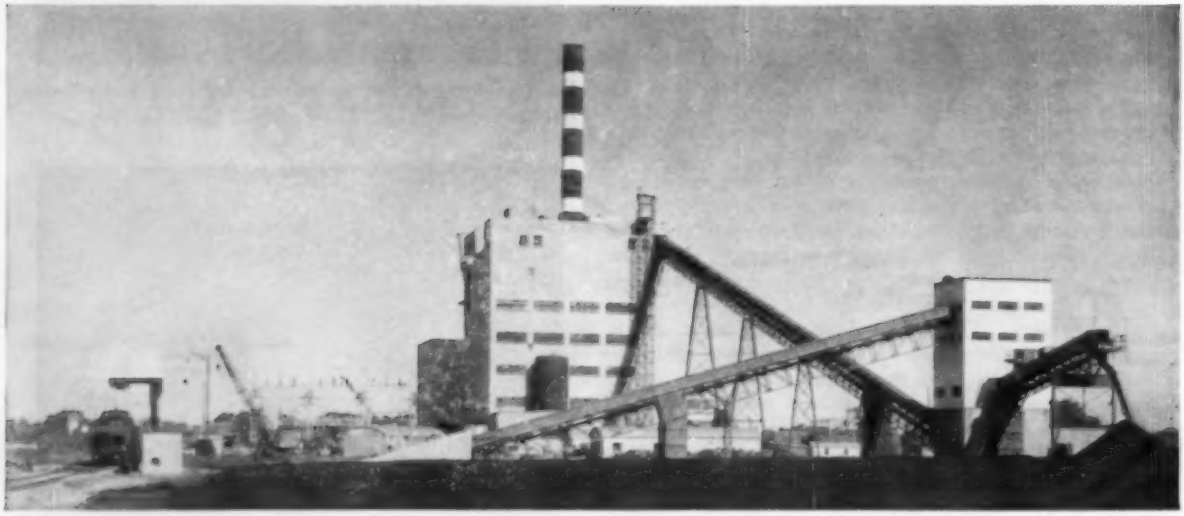
Fuel consumption on the high-pressure gas furnaces is averaging approximately 4,620,000 Btu per ton of steel while the shop average is 4,920,000 Btu per ton. This is not good, but up until this time the emphasis has been placed on tonnage with little attention to fuel consumption. Today emphasis is being placed on fuel as well as tonnage, and surprisingly as it may seem, we have tapped heats with as little as 2,000,000 to 2,800,000 Btu per ton. This must be our ultimate goal, but there are many problems in an open hearth we must overcome before this can become a reality. The biggest problem that confronts us today is the instilling of a desire in the individual to a pride of accomplishment of his work.

Fig. 9—Camera shot, above, pictures the nose of the burner and indicates the angle at which the high pressure gas and fuel oil mix, Fig. 2, enter the high temperature zone



Above: the Blackhawk Station—Wisconsin Power and Light Company. Present capacity 50,000 kw.

Below: the Rock River Station—Wisconsin Power and Light Company. Present capacity 60,000 kw.



Teamwork Tells the Story

Blackhawk and Rock River generating stations are part of the large Wisconsin Power and Light Company power plant system. They inject 110,000 kw. of electrical power into the veins of midwest industry. Officials and the engineering staff planning with Sargent and Lundy, their consulting engineers, wisely provided for the future of both plants as power needs increase. Significantly, dependable Rex® Conveyors perform the important coal-handling job.

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Fig. 1—Two welders working simultaneously to complete the weld in high-pressure piping

Backing Ring Elimination Permits Ultrasonic Testing and Avoids Cracking at Piping Welds*

By W. A. POLLOCK†

Wisconsin Electric Power Co.

Pipe welds made without backing rings can be examined by relatively low-cost ultrasonic inspection. Also, this technique excludes stress concentration at root of weld and the related hazard of cracking.

ELIMINATION of backing rings in all of the pipe welds at the Oak Creek Power Plant excludes the hazard of a ring being loosened by vibration or other causes and damaging turbine blading. An even greater merit, when applied to alloys such as $2^1/_4$ per cent chrome 1 per cent molybdenum (P-22), which is more notch-sensitive than carbon steel, is the exclusion of the points of stress concentration at the root of the weld and the resultant hazard of cracking.

That high-quality root beads could be made in the absence of backing-up gas, by using a tungsten electrode with an inert shielding gas, was found practical after development of proper end preparation.

A very important by-product of the effort spent in the backing ring elimination was the discovery that relatively low-cost ultrasonic inspection of the welds was entirely practical and could replace the more expensive and less satisfactory gamma-ray inspection. Periodic reinspections are readily made to learn whether the minor indications shown by the sonic test are insignificant, and whether perfect reliability is retained.

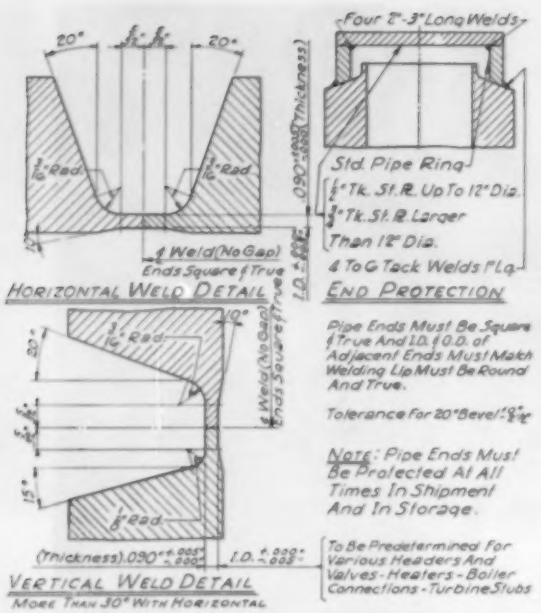
A tubular preheater element development permitted time-clock starting and indefinite holding of preheat temperature during night and week-end periods allowing the scheduling of welders and associated crafts on more desirable day shifts and eliminated necessity for round-the-clock welding of the P-22 alloy.

Description of the Welding Procedure

Adoption of the practice of welding without backing rings as standard practice with the first Oak Creek unit was the first basic change in our company's high-pressure

* Reprinted by permission of the Welding Journal and presented at the 1955 American Welding Society National Fall Meeting, Philadelphia, Pa., Oct. 17-21, 1955.

† Technical Engineer of Power Plants.


Four 2"-3" Long Welds
20°
20°
3/16" Rad.
3/16" Rad.
Std. Pipe Ring
1/2" Tk. St. R. Up To 12" Dia.
3/8" Tk. St. R. Larger Than 12" Dia.
4 To 6 Tack Welds 1" Lg.
4 Weld (No Gap) Ends Square & True
HORIZONTAL WELD DETAIL
END PROTECTION
Pipe Ends Must Be Square & True And I.D. & O.D. of Adjacent Ends Must Match Welding Lip Must Be Round And True.
Tolerance for 20° Bevel
Note: Pipe Ends Must Be Protected At All Times In Shipment And In Storage.
3/16" Rad.
1/8" Rad.
15°
(Thickness) .090" +.005 -.000
I.D. +.000 -.008
To Be Predetermined For Various Headers And Valves - Heaters - Boiler Connections - Turbine Stubs
VERTICAL WELD DETAIL
MORE THAN 30° WITH HORIZONTAL

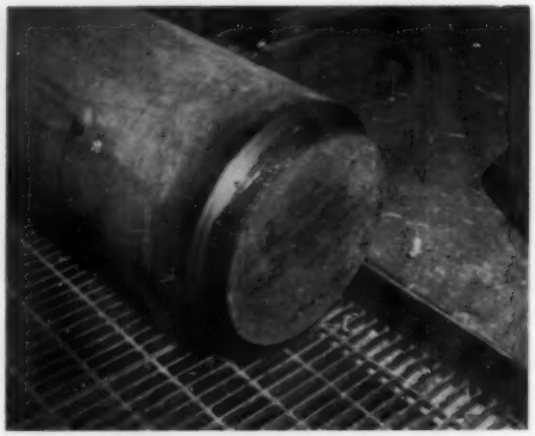


Fig. 3—End protection shown on a 15¾", OD pipe as delivered to plant

Fig. 2—High-pressure welding end detail—typical

pipe-welding procedure since pipe-joint welding was adopted in the mid-1930's.

Figs. 2 and 3 show the typical welding-end detail. Special precautions proved necessary in practice and incorporated in the drawing are the infallible protection of the pipe ends against damage during shipment, and the unusually close tolerances which experience with three units and approximately 1000 welds has proved practical.

Perfect matching of the internal diameters, readily obtained by slight internal turning at the fabricator's shop, is required to eliminate "stress raisers." To minimize the amount of turning, the fabricator preselects the pipes which are to be used for each pipe connection. Accurate alignment of matching pipe ends as well as a sufficient length of small cross section at the pipe end are required to prevent cracking when the pipes are joined by fusing the ends without the addition of filler metal.

Early experiences with this welding procedure were discouraging. The first designs of end protection were not satisfactory and many pipe ends needed repair prior to aligning. The ends on the early welds were not truly matching and there was considerable difficulty in fitting. Now that the ends are properly prepared there is very little need to do any field fitting work. Actually, there is no reason why precision fits cannot be supplied for pipe ends as well as for machine parts. It is only a matter of obtaining cooperation of the fabricator.

A 0.004-in. clearance is the usual maximum opening allowed between pipe ends as they are lined up. This maximum clearance is realized by minor filing of the "lips" in case minor fitting is a necessity.

The fabricators are requested to avoid painting 3 ft of each pipe end because this paint melts and contaminates the weld. As shown in Fig. 4, the pipe ends are thoroughly cleaned and dried and then are held in position by strong bolted clamps instead of tack welds while preheater elements are attached to the pipes to be heated. The cleaning contributed to noncracking of root weld. An aluminum flux is applied as soon as alignment is complete and clamps are tightened, Fig. 5.

Tubular preheater elements, discussed later in this paper, are clamped to the pipes, as shown in Fig. 6. Temperature is maintained at 600 F during the entire welding process. Wisconsin Electric Power Co. specifications permit cooling after half of the wall thickness has been welded. This is done when a week end or holiday interrupts continuous working.

The root pass, applied next, is shown in Fig. 7. This is followed by two passes with $^{5}/_{32}$-in. coated electrodes and the remaining passes to completion by using $^{1}/_{8}$-in. and $^{1}/_{8}$-in. electrodes, illustrated in lead photo, i.e., Fig. 1. Slag and pinhole removal is by wire brush, rotary files and grinding wheels, as shown in Fig. 8.

Next, the weld is stress relieved at 1350 F by induction heating using 750,000-cm flexible cable (Fig. 9), and finally the completed weld is checked carefully with a shear wave ultrasonic test apparatus, pictured in Fig. 10. The pipe is allowed to cool between completion of weld and stress relief.

Examination of the root-pass surface within the pipe has proved many times that it is favorably smooth and free of scale. It may be curved slightly inwardly or outwardly, but it has no stress raisers. The outward curving occurs only when tight fitting is not done in aligning. Practically all welders can qualify for consistently smooth interior surface after receiving proper training.

Backing Ring Elimination Considerations

Failure of a welded joint in the steam line of the Springdale Station of the West Penn Power Co. in January 1943, as a result of graphitization, focused the attention of the power industry on the need for extreme care in the selection, design, fabrication and erection of high-pressure, high-temperature piping. Millions of dollars have been spent, consequently, for research, for repair, and for replacement of piping in which graphitization occurred due to operation temperatures in ex-

Fig. 4—Clamps maintain alignment instead of tack welding

Fig. 5—Aluminum flux being painted on pipe ends after alignment. No gap is important for crack elimination

cess of those desirable for 0.5 per cent molybdenum piping.

R. W. Emerson (1)[1] published a picture of a welded joint, exhibiting intergranular graphitization at the extremity of weld heat-affected base metal. That photograph, reproduced in several of the subsequent articles on the subject (2, 3) and a photograph in another article (4), were, in part, responsible for investigations by our company, not only into graphitization, but also into the method whereby backing rings could be eliminated when making welds in high-pressure piping and thus eliminate the stress raiser.

The photograph in Emerson's paper shows a weld joining two pipes and a recessed backing ring on the inside of the pipe. The backing ring is not tightly adherent to the inside of the pipe, but a gap equal to the thickness of the backing ring exists. The ring has apparently been caused to warp away from the inside pipe wall by the welding and stress-relieving processes. Cracks are evident at the root of the weld joining the backing ring and the pipe metal.

That these cracks exist is not unexpected because of the notch at this junction. In operation, at each alternate heating and cooling, the backing ring, due to its relatively lesser thickness, heats up and cools down more rapidly than the adjacent pipe and high stressing of the notch results.

The void between the pipe and the backing ring occurs even though the rings are tailor-made in the field. The void affords an excellent location for corrosion to start, especially in boiler feed lines, due to oxygen. If acid cleaning is practiced, it is almost impossible to neutralize all of the acid, and corrosion takes place under the ring.

Potential Accidents Initiating with Backing Rings

Several unfavorable experiences with backing rings at the Port Washington power plant of our company hastened the investigations which led to the ultimate elimination of backing rings. A backing ring in an 18-in. reheater outlet line was found loose and was removed from the pipe without the aid of any kind of a tool. This backing ring had been installed by a piping fabricator when he was welding a short length of pipe to a gate valve. Welders had not fused the ring and the pipe together and an inspection revealed that slag from the welding electrode had filled the space between the ring and the pipe. Had not this loose ring been found it might ultimately have worked its way into the turbine blading because that ring was not recessed and there was no strainer between it and the turbine.

On another occasion, a section of carbon-molybdenum pipe was removed after several years' service to install steam dump valves in the reheater lines between the outlet from the reheater and the inlet to the turbine. The welds in the removed section were examined for graphitization and some separations between the backing ring and pipe were found.

Internal inspection of boiler feed lines at the boiler feed pump discharge flanges and through check valves revealed that corrosion under the backing rings has occurred due to oxygen in the feedwater at start-up and during very low loads, as well as due to acid attack from acid introduced when cleaning the water side of extraction heaters. In some cases the backing rings are more than half gone, even though there is only minor attack on the inside pipe wall. The turbulence they cause is destructive of natural protective coatings.

A June 15, 1955, report of an inspection of boiler feed piping and check valves from Port Washington power plant stated in part as follows:

No. 7 Boiler Feed Pump

The valve body was clean and there was no evidence of new erosion.

Piping on the upstream side to the bend was in good condition and clean to touch. The weld joint, where valve body and piping meet, was made in November of 1954 after piping was removed to permit weld repair of a valve body leak. No backing ring was used. Inspection was by sight only, as writer could not get arm through valve body and into pipe in that direction.

Piping on the downstream side of the check valve was

[1] Numbers in parentheses refer to Bibliography at the end of the article.

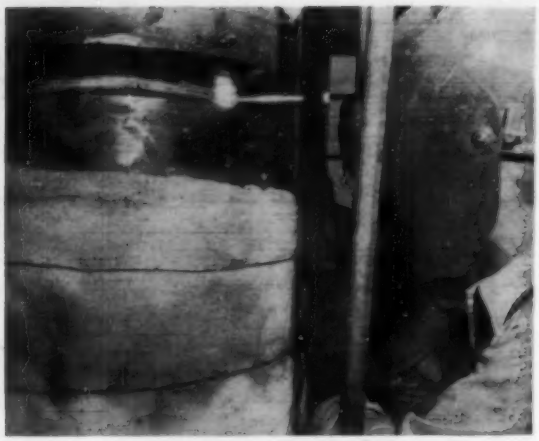


Fig. 7—Inert gas arc weld used for root bead

Fig. 6—Tubular preheater elements are easily installed and are unusually rugged and reliable

also in good condition, smooth and clean, to the discharge valve. The backing ring at the weld where the valve body and pipe are joined has been eroded away. A $^1/_8$-in.-deep groove exists around the circumference.

No. 9 Boiler Feed Pump

The valve body was clean and showed no new signs of erosion.

Piping on the upstream side of the valve to the first bend was clean and in good condition. The backing ring at the weld where piping joins the valve body has been eroded away. A groove $^1/_8$ in. deep in relation to pipe surface, and $^1/_4$ in. deep in relation to valve body diameter exists at this point.

On the downstream side of the valve, to the first bend, piping also appeared to be clean and in good condition. The backing ring at the weld where piping joins the valve body showed signs of erosion. About 90 deg of the ring circumference at the top of the pipe is eroded considerably, and similar erosion has occurred at the 7 o'clock position, looking downstream. Some metal loss from the valve body just ahead of the backing ring was noted at the latter location (7 o'clock).

That backing rings were entirely eroded away in piping operating since October 1948 is alarming. Whether the rings waste away or break off in larger pieces cannot be predicted. If the latter occurs, serious troubles may be expected. The adjacent pipe was not similarly eroded, and one is caused to wonder about the condition of all of the rest of the backing rings which cannot be inspected. One important change in operation to arrest further corrosion has been substitution of demineralizers for evaporators with the benefit of preventing carbon dioxide from entering the pre-boiler cycle.

Early Developmental Work Initiated

Adoption of 1000 F steam temperature at Oak Creek resulted in selection of the $2^1/_4$ per cent chrome 1 per cent molybdenum alloy.

Search of the literature at that date did not reveal that anyone had developed a satisfactory method of welding high-pressure alloy pipe in the absence of backing rings although as early as 1947 an article by Eric Seabloom (5) discussed alloy pipe welding and showed a welding groove without a backing ring.

Conferences were held with Messrs. John Chyle and R. Keller of A. O. Smith Corp., L. J. Larson of Allis Chalmers Co., F. Boicourt and V. Rowland of Travelers Insurance Co.; and many valuable suggestions were received. Many tests were conducted using an acetylene torch with and without filler rods, and various coated welding rod sizes and weld-end details were tried in an attempt to weld without backing rings. The $2^1/_4$ per cent chrome 1 per cent molybdenum alloy pipe which was to be used at Oak Creek power plant was used in these trials. Finally the inert gas welding torch with nonconsumable electrode was adopted. Backing-up gas was found unnecessary with the design of welding groove adopted, as shown in Fig. 2.

The practice of welding all high-pressure steam and water piping without backing rings became standard company practice with the first Oak Creek unit. The insurance company afforded unqualified approval after helping develop and test the procedure.

To join the pipe ends properly, the experience with Oak Creek 1 showed that it was necessary to protect the ends adequately in shipping and erecting. The fabricators have cooperated and furnished the matching ends to the internal diameter tolerance of $+0.000$, -0.005 in. The close fitting of the internal diameters and complete penetration of the inert arc root weld have completely eliminated the stress raisers and provided the smooth inside surfaces so necessary to properly inspect with ultrasonic test methods. The $^5/_{32}$-in. straight section of the pipe end is approximately $^1/_{16}$ in. more than actually needed, but this excess has been found desirable to allow some filling for fitting when bends are not exactly as specified.

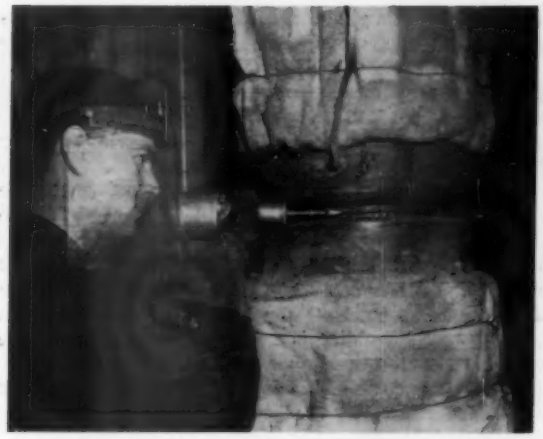


Fig. 8—A rotary file is used to remove slag and pinholes

Fig. 9—Stress relieving by induction heating follows weld completion. Cables at left with connectors at each elevation provide stress reliever supply with minimum cable handling. A second weld is being stress relieved on right

Ultrasonic Test Method Adopted

Ultrasonic testing was first used by the writer's company to inspect the pipe ends for imperfections. This was reported in a discussion of a paper in 1951 by the writer (6). One crack several inches long and $^1/_8$ in. deep, which was found in an elbow next to a reheater header on a Port Washington unit, was repaired, preventing a possible forced outage. It was natural that, after the internal surface of the pipe was smooth because the backing rings were eliminated, ultrasonic testing was considered as a pipe weld inspection method. A previous trial of the ultrasonic method of weld inspection with backing rings at Port Washington had proved unsuccessful because of the interference reflection of the backing ring.

Specimens with known defects such as slag inclusions, lack of penetration to the root and cold shuts were put deliberately in a test weld. All were located reliably by the service engineer, in qualifying the ultrasonic method of testing. It was concluded that ultrasonic inspection of welds of the type tested was "possible with clear and consistent results" (7).

In service, minor defects were found but in all cases they were less than that allowed by the ASME code for piping defects when using gamma-ray testing. After one year of operation these welds were reinspected, and the same defects were located and found to be of the same magnitude as they were originally.

An engineer of one of the large insurance companies observed the test, and the qualification test was arranged with his assistance. His company has given its approval to this test procedure when the test is administered according to the established procedure.

This use of ultrasonic inspection of welds was not new. Its use was predicted in 1950 by W. B. Bunn and W. J. Mitchell (8). Their report stated in part, under the heading "Weld Inspection": There is no question that ultrasonics will also find its use in weld inspection. Equipment is quite portable and reasonably fast. However, it has certain basic deficiencies, among which are: (1) lack of a permanent record, (2) greater dependence on skill and integrity of the operator and (3) difficulty in establishing a standard of acceptance that will detect minor but dangerous discontinuities in the root areas of the weld."

We believe that the taking of pictures of the screen of the instrument when indications are found by ultrasonic testing will provide a permanent record. This, accompanied by a careful log of test observations, will provide as good a record as the steel forging manufacturers furnish turbine manufacturers for their large turbine and generator forgings. Then, too, a recheck is made easily by simply removing the pipe insulation during an outage, and repeating the initial tests. The complete weld can be reinspected at such times.

There is no substitute for a skillful and dependable ultrasonics operator. Our company is so convinced of this that it prefers to employ a commercial inspection service in order to obtain the best in experience and test technique.

The elimination of the backing ring has reduced the problem of obtaining a good ultrasonic indication of the condition at the root of the weld. Further, it has been found that if the pipe walls do not line up perfectly, by examining the weld from both sides, it is possible to evaluate accurately the amount of difference in the internal diameters. If examination from one side of the weld gives an indication and from the other side gives none, one can safely conclude that there has been 100 per cent penetration to the inside diameter of the larger pipe diameter. If there is an indication from both sides, the lesser of the two indications can be taken as the amount of lack of penetration.

Proposed New Standard for Ultrasonic Inspection

There is much to be said for establishing standards of inspection. Up to the present time it has been usual practice to make up a test piece of pipe to provide curvature and wall thickness exactly like that to be tested and to simulate a defect of 1 per cent by making a small chisel mark in the surface. This has given a far greater sensitivity than is apparently desirable, and due to this high sensitivity the inspection is slowed down somewhat. It is believed that the standard should be established by drilling a hole into the test pipe with a flat bottom drill with a diameter 2 or 3 per cent of the wall thickness. This hole should be drilled at the same angle as that at

which the ultrasonic crystal transmits its beam so the beam will strike the bottom of the hole squarely.

Advantages of Ultrasonic Testing

The several advantages of ultrasonic inspection are: (*a*) rapid; (*b*) relatively inexpensive when compared to X-ray or gamma-ray; (*c*) the equipment is very portable, especially now that a smaller one-wave tester has been developed; (*d*) retests may be made of areas where minor defects are noted, these retests being on a periodic basis to learn whether the defects need removal or repair; (*e*) at these reinspections the entire weld is reexamined for soundness; (*f*) these reinspections do not require drilling a hole for the radioactive cobalt insertion and the subsequent rewelding and stress relieving of the repair; (*g*) an independent referee is obtained when the inspection is contracted for through a company providing this service.

Tubular Preheater Element Development

Preheating the $2^1/_4$ per cent chrome 1 per cent molybdenum piping during the several shifts of welding presented somewhat of a problem.

Most authorities agree that it is desirable to maintain preheat temperature through at least half of a weld. Many contend that the weld should not cool down until the weld is completed and some recommend that the stress relieving follow welding immediately. Because no adverse effects could be found in tests when half of the weld was completed before allowing cooling, that procedure was adopted.

Preheating by resistance elements is favored over induction coils because of the less expensive equipment requirements. Then, too, when induction coils are used, it is necessary to shut off the current during welding. The only resistance elements offered by the manufacturers for this service were 250-watt strip heaters which were strung together in No. 10 solid wire to produce adequate heating capacity. These heaters were not rugged and failed due to short circuits, burnouts and mechanical damage. The delays caused by failures were time consuming and the man-hours lost due to the delays were expensive.

A tubular preheater element of 2100 watts bent in a sinusoidal shape, designed and made up for trial, proved satisfactory and was adopted for Oak Creek 2. Several advantages have accrued, affording savings of over $16,000 for the 350 welds of each unit.

Since the heaters are flexible enough to form to the various pipe diameters, only one size is needed. No cleaning or preparation is required after the heaters have been used in order to prepare them for the next weld. The fitters can fasten them to the pipe with a single stainless steel strap which is tightened with a bonding tool. Welding is conducted on a day schedule and heat is maintained over week ends without anyone in attendance. The heat is turned on by time clock during the night prior to start of a weld and is up to the desired temperature at the beginning of the shift.

Information on design details and procurement of these heaters will be furnished upon request.

Fig. 10—Ultrasonic inspection. The engineer, using an angle crystal, probes for indications of flaws. The standard specimens for calibrating the instrument are at the left

Acknowledgment

In addition to valued assistance of the representatives from Travelers Insurance Co., A. O. Smith Corp. and Allis-Chalmers Manufacturing Co., it is a pleasure to acknowledge encouragement of Messrs. M. K. Drewry and O. J. Stallkamp in preparing this paper as well as their counsel in development of the welding program. Messrs. Walter Goetz, Martin Goetz, Carl Thiele, C. Bergquist, W. J. Hellen and L. J. Niebler have been generous with assistance in developing and carrying out the details outlined herein. Messrs. N. Marinin and P. Markiewicz rendered valuable assistance in developing the welding technique. In addition to the above fellow employees of Wisconsin Electric Power Co., Mr. Sheldon Leonard of Sperry Products, Inc., has also assisted materially in making this program successful.

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Sound engineering for flood control of the small rivers and streams of the northeastern United States, based on proper information, must be undertaken in order to prevent a recurrence of the recent New England disaster, according to **W. W. Horner,** chairman of the **Engineers Joint Council Water Policy Panel.**

As far back as 1951, according to Mr. Horner, the Engineers Joint Council reported this lack of important information of the New England rivers and recommended the installation of more measuring devices in the area.

Test of Accuracy of Sampling Mixed Coals with Small Increments

By R. L. CORYELL,* and F. J. SCHWERD,†

Consolidated Edison Co. of New York, Inc.

Test data have been obtained on sampling of coal with small increments taken by hand and variances determined on each step of the sampling, reduction and analysis. Each step was also tested for bias and no evidence of bias was found. A high increment sample variance was found, and reduction and analysis variances were larger than had been expected. These large variances indicate that with 3-lb increments the present ASTM coal sampling requirements are inadequate.

DURING 1952 a study (1)[1] was made of the coal sampling at one station using mechanical samplers which collect large increments (50 lb.). That study was extended during 1953 to obtain the accuracy of the manual sampling procedures. This paper describes the later studies.

In any tests of accuracy of sampling it should be established that there is no significant bias in any of the steps in the sampling procedure. It is essential that preliminary tests be made for such bias and that any bias found in the coal sampling or in the subsequent reduction and analysis be eliminated.

The tests on the manual sampling of coal were therefore designed to include:

1. Tests for bias at any state of the sampling operations.
2. Determination of the sampling variance. This variance value includes both the trend and the increment variances for the coal.
3. Determination of the variances of the reduction of the sample to a laboratory pulp.
4. Determination of the variance due to small random errors in the laboratory analysis.

For these tests only mixed coals were sampled as theoretically they offer higher variances than individual coals. These variances are based on the ash analysis of the coal samples as this constituent provides the most sensitive measure of changes in coal quality.

Station Coal Sampling Procedure

The incoming coal is crushed to minus $1^1/_2$ in. size at each of three unloading towers and is fed to lorry cars which carry it to the boiler feed hoppers. Each lorry car (size 8 ft × $6^1/_2$ ft × $5^3/_4$ ft) holds approximately five tons. On one side of each car, at mid-height, is located a sampling opening (approximately 6 in. × 7 in.) with a sliding door.

Every fourth car is normally sampled by opening the door and inserting a scoop. The hand samples so obtained are collected in large, covered cans. Upon completion of the sampling of a cargo, the gross sample is crushed to 95 per cent passing a No. 4 sieve by means of a crusher sampler, which collects a fixed fraction of the coal through a "save" spout.

This "save" portion is riffled by hand to produce two final samples which are placed in five gallon cans and sealed. One sample is sent to the laboratory for reduction and analysis. The duplicate is retained as a station reserve sample.

Preliminary Tests for Bias in Hand Sampling Procedure

Preliminary tests for the presence of bias were made at the crusher-sampler by collecting ten special gross samples of approximately 50 lbs each taken by sampling scoop in the same manner as the regular cargo samples. This test program is shown diagrammatically in Fig. 1. Each sample was put through the crusher-sampler and divided into "save" and "reject" portions. These were later reduced and analyzed for ash.

In addition, duplicate pulps were prepared and analyzed from the "save" portions as a preliminary check on the accuracy of the laboratory reduction and analysis. Results of these tests are shown in Table I.

A statistical comparison of the results was made to determine the probability of bias. The method used was the null hypothesis for comparing two sample universes. This method assumes that no bias exists if the ratio of the average difference between pairs to the standard deviation of that difference is less than the critical value of "t" for a specified level of probability.

$$-t \lesssim \frac{\bar{d}}{s_d}\sqrt{n} \lesssim t$$

Where:

$\bar{d}$ = average difference between pairs of analyses
s_d = Standard deviation of the difference

Editor's Note: Two articles by these same authors will follow. The one reports on the accuracy of top sampling of railroad cars and the second on the accuracy of laboratory preparation and analysis of coal samples.

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[1] Numbers in parentheses refer to similarly numbered references in the Bibliography at the end of the paper.

n = Number of pairs of analyses
t = Limiting ratio for $(b-1)$ degree of freedom at the probability level desired

Calculations by this method yielded the following results:

	No. of pairs	$\bar{d}$	$s_{\bar{d}}$	t	Critical Value of "t"
Save "A" vs Reject	10	−0.17	0.61	0.881	2.262
Save "B" vs Reject	7	−0.01	0.49	0.083	2.447
Save "A" vs Save "B"	7	+0.01	0.56	0.072	2.447

Further tests of the probability of bias at the various states of reduction and analysis were also made in the course of the main test program, by making a similar statistical comparison of pairs of analyses at each step. None of these comparisons showed statistical evidence of any bias in the reduction and analysis of the coal samples.

TABLE I—RESULTS OF PRELIMINARY TEST ON CRUSHER ASH ANALYSES OF SAVE AND REJECT PORTIONS

Sample No.	Save Portion "A"	Save Portion "B"	Reject
1	10.1	...	11.6
2	6.9	...	7.2
3	8.3	...	8.2
4	12.6	13.1	12.4
5	13.0	12.0	12.5
6	10.9	11.0	10.9
7	12.6	12.7	12.2
8	11.5	11.0	11.3
9	11.2	11.3	11.9
10	12.2	12.8	12.8

Tests of Accuracy of Hand Sampling

A test program was set up to furnish the necessary data for the determination of the overall accuracy of hand sampling of coal with small increments (i.e., approximately 3 lb each). As shown diagrammatically in Fig. 2, this program also provides for collection of data on the subsequent steps in the reduction and analysis of these sample increments.

For this test sixty small increment samples were taken manually, two from each of 30 cargoes. No two increments were taken from adjacent portions of a cargo. Each increment was placed in a friction top can, weighed and sent to the laboratory where it was reduced and analyzed for ash content. In the laboratory each sample was divided after crushing to 20 mesh and each portion analyzed separately.

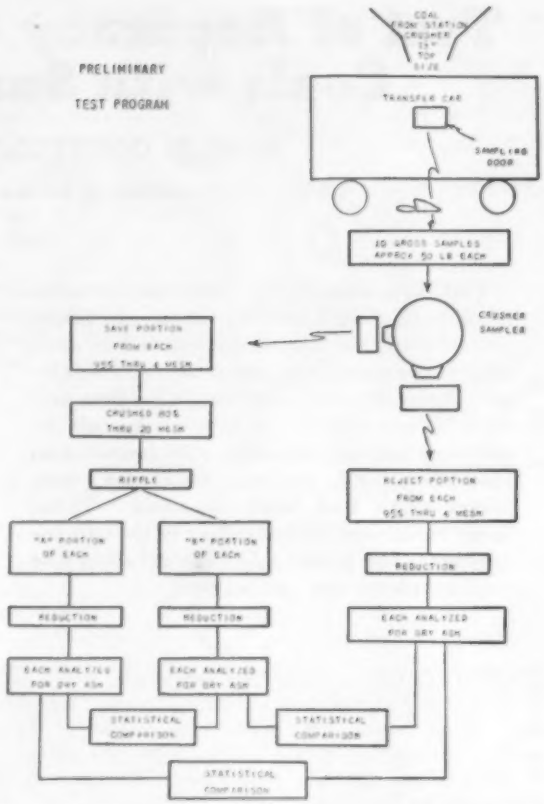

Fig. 1—Preliminary tests for the presence of bias were made at the crusher-sample and handled as the diagram shows above

Portions of the regular station samples were also obtained to check the accuracy of the reduction and analysis. Twenty-one separate cargo samples were prepared by taking the reject from the regular sample and dividing same in the crusher-sampler. Each "save" portion was then reduced in the regular manner and analyzed for ash.

The results of these tests are shown in Tables II and III.

TABLE II—RESULTS OF HAND SAMPLING TESTS, SPECIAL INCREMENTS

Incr. No.	Weight, Kgm	Per Cent Ash "A" Portion	Per Cent Ash "B" Portion	Incr. No.	Weight, Kgm	Per Cent Ash "A" Portion	Per Cent Ash "B" Portion
1	1.710	7.4	..	29	1.560	10.9	10.9
2	1.940	12.1	..	30	1.640	10.8	11.0
3	1.315	8.7	..	31	1.390	9.1	9.1
4	1.276	8.2	..	32	1.460	11.7	11.3
5	2.280	11.2	..	33	1.610	9.7	10.0
6	1.418	11.8	..	34	1.558	10.4	10.6
7	1.578	7.4	..	35	1.501	10.2	9.8
8	1.434	10.5	..	36	1.350	10.2	9.9
9	1.387	8.2	..	37	1.505	8.5	8.4
10	1.511	9.7	..	38	1.404	9.1	8.8
11	1.350	10.7	..	39	1.475	10.6	10.2
12	1.330	8.5	..	40	1.542	9.9	10.0
13	1.470	7.7	..	41	1.545	8.2	8.6
14	1.472	7.1	..	42	1.550	7.8	7.8
15	1.430	10.3	..	43	1.610	10.3	10.4
16	1.495	5.7	..	44	1.575	9.9	9.9
17	1.400	10.3	..	45	1.470	9.0	9.1
18	1.513	11.5	..	46	1.362	10.1	10.5
19	1.530	12.5	..	47	1.303	9.2	9.3
20	1.525	11.0	..	48	1.513	9.5	9.1
21	1.452	8.0	..	49	1.628	11.8	11.7
22	1.493	8.3	..	50	1.650	11.6	11.0
23	1.565	11.9	..	51	1.530	10.3	10.1
24	1.370	12.0	..	52	1.395	11.8	12.1
25	1.985	10.0	..	53	1.490	7.9	8.3
26	1.482	7.8	..	54	1.488	14.7	13.3
27	1.430	8.3	..	55	1.886	9.7	10.0
28	1.570	8.8	..	56	1.570	6.8	6.8
				57	1.513	8.5	7.3
				58	1.488	5.8	5.5
				59	1.570	12.2	11.8
				60	1.720	11.7	11.4
Totals	42.707	265.6	..		48.851	317.9	316.0
Averages	1.525	9.49	..		1.527	9.93	9.88

TABLE III—RESULTS OF HAND SAMPLING TESTS, CARGO SAMPLES

Sample No.	Per Cent Ash Regular Cargo Sample	Per Cent Ash Special Sample
1	11.2	9.6
2	9.1	9.2
3	11.2	11.5
4	9.9	9.4
5	11.7	11.2
6	11.5	11.2
7	8.6	8.6
8	8.5	8.8
9	11.1	11.8
10	11.3	12.3
11	10.9	10.2
12	8.4	8.1
13	10.5	10.2
14	11.3	11.8
15	10.1	10.7
16	9.6	10.4
17	9.6	9.8
18	12.4	12.3
19	11.9	12.3
20	11.0	11.3
21	10.0	10.3
Averages	10.4	10.5

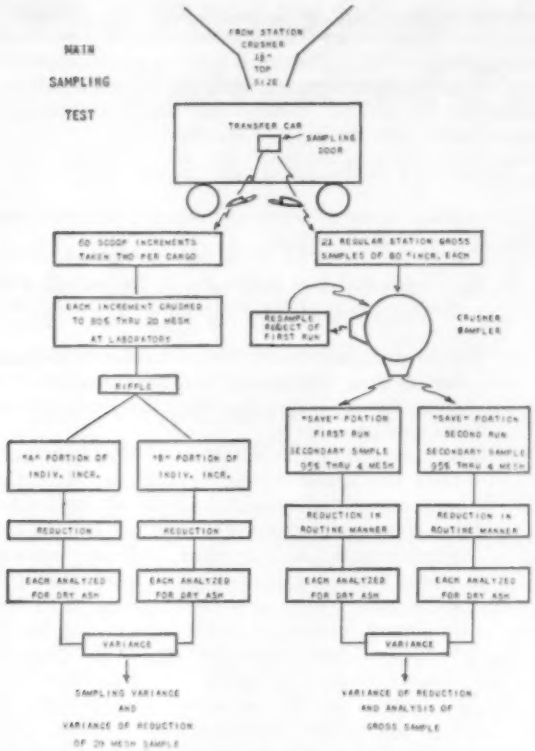
MAIN SAMPLING TEST
FROM STATION CRUSHER 1½" TOP SIZE
TRANSFER CAR
SAMPLING DOOR
60 SCOOP INCREMENTS TAKEN TWO PER CARGO
EACH INCREMENT CRUSHED TO 80% THRU 20 MESH AT LABORATORY
RIFFLE
"A" PORTION OF INDIV. INCR.
"B" PORTION OF INDIV. INCR.
REDUCTION
REDUCTION
EACH ANALYZED FOR DRY ASH
EACH ANALYZED FOR DRY ASH
VARIANCE
SAMPLING VARIANCE AND VARIANCE OF REDUCTION OF 20 MESH SAMPLE
22 REGULAR STATION GROSS SAMPLES OF 60 INCR. EACH
RESAMPLE REJECT OF FIRST RUN
CRUSHER SAMPLER
"SAVED" PORTION FIRST RUN SECONDARY SAMPLE 95% THRU 4 MESH
"SAVED" PORTION SECOND RUN SECONDARY SAMPLE 95% THRU 4 MESH
REDUCTION IN ROUTINE MANNER
REDUCTION IN ROUTINE MANNER
EACH ANALYZED FOR DRY ASH
EACH ANALYZED FOR DRY ASH
VARIANCE
VARIANCE OF REDUCTION AND ANALYSIS OF GROSS SAMPLE

Fig. 2—A test program as above was set up to furnish data for determining the overall accuracy of hand-sampling with small increments

Since the tests of accuracy of any coal sampling are dependent on the accuracy of the laboratory reduction and analysis, observations were made at the laboratory over the period of these tests. For this purpose, thirty of the regular samples received at the laboratory were riffled twice to produce replicate samples. Each sample was then reduced to a pulp in the regular manner and analyzed for ash. Over the same period duplicate analyses were made on sixty pulps of other shipment samples. Tables IV and V show the results of these tests.

A statistical analysis of these results for the determination of the probability of bias in the various steps of reduction was made in the same manner as described in the discussion of the preliminary tests.

The following results were obtained:

	No. of Samples	Std. Dev. of Diff.	Avg Diff.	Value of "t"	Critical Value of "t"
Reduction and analysis of Gross Sample	21	0.59	0.06	0.623	2.080
Reduction and analysis of Lab. Sample	30	0.51	0.10	1.105	2.042
Reduction and analysis of 20 Mesh Sample	32	0.37	0.06	0.914	2.038

These results confirmed the findings of the preliminary studies that there was no evidence of bias in any stage of the reduction.

The sampling variance ($s_t^2 + s_i^2/w$) of the 3-lb increments was computed from the data given in Table II. Comparison of the pairs of analyses at each stage of reduction and analysis provided the variances of each of these steps.

The results of these computations were as follows:

Sampling variance of individual 3-lb increments ($s_t^2 + s_i^2/w$)		2.9647
Variance of Station Reduction to 4 Mesh Sample	0.0484	
Variance of Reduction to 20 Mesh Sample	0.0641	
Variance of Reduction to Laboratory Pulp	0.0504	
Variance of Analysis	0.0139	
Variance of Reduction and Analysis of Gross Sample (s_{ra}^2)		0.1768

This variance value of 0.1768 for the reduction and analysis of the hand samples compares closely with the corresponding value of 0.1763 obtained on the mechanical samples (1). This close check over a period of two years indicates consistent preparation and analysis of the samples in the electric stations and at the laboratory.

The number of increments required for a specified accuracy with the procedure tested was calculated from the Bertholf formula.

$$N = \frac{s_t^2 + s_i^2/w}{Ls_r^2 - \left[\frac{s_r^2 + s_a^2/k}{p}\right]}$$

TABLE IV—RESULTS OF LABORATORY REDUCTION AND ANALYSIS OF COAL SAMPLES CRUSHED TO PASS NO. 4 SIEVE

	Per Cent Ash				
	Reduced Portion				
Item	AA	AB	BA	BB	Average
1	9.5	9.6	9.7	9.4	9.6
2	8.5	8.1	8.0	8.1	8.2
3	8.4	8.5	8.0	7.8	8.2
4	10.8	11.1	10.1	10.8	10.7
5	11.3	12.7	11.9	10.7	11.7
6	8.7	8.8	8.7	8.5	8.7
7	8.6	9.2	8.2	8.2	8.6
8	8.9	10.0	9.8	10.3	9.8
9	8.9	8.8	9.0	8.4	8.8
10	7.9	7.7	8.0	8.2	8.0
11	8.7	8.2	8.1	8.2	8.3
12	8.0	8.2	8.6	9.0	8.5
13	8.5	8.5	8.5	8.0	8.4
14	8.3	8.9	8.6	9.8	8.9
15	8.5	8.6	8.2	8.6	8.5
16	9.4	9.7	9.2	9.4	9.4
17	9.2	9.3	9.4	9.5	9.4
18	10.1	10.5	10.1	10.5	10.3
19	13.4	14.1	14.0	14.0	13.9
20	8.2	8.9	8.7	8.1	8.5
21	8.6	9.3	8.9	9.7	9.1
22	11.2	12.0	12.8	11.9	12.0
23	7.5	7.6	7.6	7.6	7.6
24	9.0	9.2	9.3	9.1	9.2
25	8.9	8.8	9.0	8.9	8.9
26	8.9	8.9	9.2	9.1	9.0
27	9.1	8.9	9.6	9.2	9.2
28	8.8	8.2	8.2	7.9	8.3
29	9.0	8.7	9.0	8.9	8.9
30	8.5	8.4	8.7	8.8	8.6
Totals	273.3	279.4	277.1	276.6	...
Averages	9.11	9.31	9.24	9.22	9.22
Standard deviation of error					0.36

TABLE V—DUPLICATE ANALYSES OF LABORATORY PULPS PER CENT ASH

Pulp No.	Original Analysis	Second Analysis	Pulp No.	Original Analysis	Second Analysis
1	9.1	9.2	31	8.4	8.4
2	8.3	8.5	32	8.4	8.6
3	10.0	9.9	33	10.1	9.9
4	8.8	8.5	34	10.6	10.8
5	7.2	7.3	35	9.9	9.9
6	7.0	7.2	36	7.3	7.5
7	8.9	9.1	37	10.6	10.6
8	11.7	11.8	38	8.6	8.6
9	10.0	9.8	39	8.5	8.3
10	9.5	9.4	40	12.9	12.7
11	9.1	8.9	41	11.5	11.5
12	9.3	9.4	42	9.8	9.9
13	8.2	8.3	43	6.3	6.6
14	8.0	7.9	44	9.9	9.8
15	9.9	10.0	45	8.9	9.1
16	8.5	8.5	46	9.0	9.1
17	6.4	6.3	47	9.0	8.7
18	13.9	14.0	48	8.7	8.3
19	7.5	7.5	49	8.8	8.7
20	9.4	9.5	50	13.0	13.2
21	8.4	8.6	51	8.7	9.2
22	8.2	8.4	52	7.9	7.9
23	7.4	7.3	53	9.1	9.3
24	8.2	8.3	54	10.8	10.7
25	9.1	9.0	55	10.1	10.0
26	7.2	7.2	56	10.4	10.4
27	7.8	7.9	57	8.4	8.4
28	8.8	8.9	58	8.9	9.0
29	8.3	8.3	59	10.0	10.1
30	7.5	7.5	60	11.2	11.0
Totals	...	...	...	547.3	548.6
Averages	...	...	...	9.12	9.14

This gave the following results for coal of the average ash content of the sixty increments tested (9.7 per cent).

	For Commercial Purposes ±10% of Ash Content			For Special Purposes ±5% of Ash Content	
	Indicated by Test Results	Required by ASTM	Over 1000	Indicated by Test Results	Required by ASTM
Size of lot, tons	*	1000	1000	*	1000
No. of Gross Samples	1	1	1	4	1
Total No. of Increments	51	20	80	204	80
Weight of Increments, lb.	3	6	6	3	6

* According to Bertholf's formula, the number of increments is independent of the size of the lot.

These data show that the number of 3-lb increments for the "commercial purpose" accuracy is greater than required by ASTM for lots under 1000 tons. Interpolating between the values obtained in these tests and the results of the mechanical sampling test 50-lb increment, the number of 6-lb increments required is found to be 30, which is still more than specified in the ASTM procedures.

For "special purpose" sampling, regardless of increment size, it appears necessary to take four separate gross samples, each as large as that needed for "commercial purpose" sampling with that size increment. Merely taking four times the number of increments combined in a single gross sample, as given in ASTM specifications, will not give the desired sampling accuracy. Since the variance required to meet the accuracy specification for "special purpose" sampling of this coal is 0.0588, and the variance of reduction and analysis found in these tests is 0.1768, it is evident that a single gross sample will not suffice. To meet this specification, at least four gross samples must be taken, and reduced and analyzed separately as shown above.

Comparison with Earlier Investigations

The following tabulation shows the comparison of the variance of the coal tested with that found in previous studies on similar coals.

Kind of Coal	Size	Ash Content	Increment Weight, lb.	No. of Increments	Sampling Variance
Pittsburgh	1½ raw slack	10.7	4	50	2.213
			3*		2.355
Enos (2)	2" × 0"	12.6	4*	30	2.128
			3*		2.379
Mixed	1½" × 0"	9.7	3	60	2.965

* This size increment not actually tested. Variance calculated from data on increments of various weights.

These figures show the variance of the mixed coal to be approximately 25 per cent higher than the "straight" coals previously tested. This is in accord with previous expectations. This higher variance is a partial explanation of the calculated greater number of increments required for the ASTM "commercial" sampling accuracy as compared with the number specified.

Conclusions

From these tests of hand sampling of current coal cargoes it is concluded that:

1. No evidence of bias was found in the reduction of the sample at either the station or the laboratory.
2. Variance of sample reduction was found to be much higher than anticipated and points to the desirability of further investigation of sample reduction procedures.
3. The variance of the mixed coals used for these tests was about 25 per cent higher than the variance of the straight coals tested previously.
4. For "commercial purpose" accuracy the ASTM requirements for lots under 1000 tons appear inadequate. For this purpose it is indicated that either the minimum size of increments or the minimum number of increments should be increased. These requirements will also provide this accuracy for sampling lots over 1000 tons.
5. These tests confirm the earlier observations (1) that the ASTM special purpose sampling accuracies such as ±5 per cent of the ash content can only be obtained by increasing the precision of the sample reduction or by taking and analyzing several gross samples separately, as provided by the ASTM method.

Acknowledgments

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What's the low-down on blow-down?

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The Formation of Bonded Deposits in Pulverized-Fuel-Fired Boilers*

By P. H. CRUMLEY,† A. W. FLETCHER† and D. S. WILSON†

British findings on bonded deposits indicate chlorine as well as sulfur content of the coal plays an important part in the formation of these deposits with pulverized coal firing. Here is a very recent report discussing these elements and their role in deposit formation.

DEPOSITS on the external heating surfaces of boilers can cause serious reduction in the output and efficiency of the boiler plant, and by increasing the frequency with which the boiler has to be shut down for cleaning may significantly reduce availability. The work of the Boiler Availability Committee[1] has shown that the formation of alkali-bonded deposits on the high-temperature heating surfaces of boilers is caused by salts of alkali metals vaporized from the fuel bed. It has also been shown that deposits of this type are associated with the combustion of coals with a high content of volatile salts of alkali metals; since these salts are thought to be the chlorides, a correlation has been postulated between the extent of formation of alkali-bonded deposits and the chlorine content of the coals burnt. It was shown by Crossley (1)[2] that severe trouble with bonded deposits in stoker-fired boilers was likely to occur when the chlorine content of the coal burnt exceeded about 0.3 per cent.

Until recently it was thought that pulverized fuel boilers were almost immune from the formation of bonded deposits. Possible reasons for the immunity of pulverized fuel boilers compared with stoker-fired boilers were suggested by Crossley (2); these were the lower temperature, the shorter time of combustion, the greater amount of fly-ash, and more oxidizing conditions. Thus, there is probably less vaporization of salts of alkali metals and more fly-ash in a pulverized fuel boiler than a stoker-fired boiler, and accordingly the salts which condense are diluted with sufficient fly-ash to be rendered harmless.

Within the last few years, however, bonded deposits have occurred in several pulverized fuel boilers burning coals of high chlorine content. In fact, recent trials carried out by the British Electricity Authority (the results of which were communicated privately to the Boiler Availability Committee) suggest that with coals of exceptionally high chlorine content the formation of bonded deposits in pulverized fuel boilers may be even more rapid than in stoker-fired boilers. At the present time, the output of such coals is not large enough to cause any serious problem, but the problem may become serious in a few years' time owing to a large expansion in the production of high-chlorine coals.

Characteristics of Bonded Deposits

The alkali-bonded deposits found in stoker-fired boilers (usually on the superheater surfaces) have been described by Crossley. (1, 2). The deposits are thought to be formed by condensation of alkali salts on the heating surfaces; the condensed salts, which are in a semi-molten condition, then trap particles of fly-ash, building up a deposit consisting of ash particles bonded by a matrix of alkali sulfates. When examined under the microscope the ash particles and the crystalline matrix can be clearly seen, and in this way bonded deposits can be readily identified. The deposits always have a high content of alkali metal (10 to 30 per cent as alkali oxide) and of sulfate (10 to 45 per cent as SO_3).

Bonded deposits obtained from pulverized fuel boilers are generally similar in appearance to those from stoker-fired boilers, and in particular, microscopic examination shows them to consist of fly-ash particles embedded in a crystalline matrix. However, the analyses are usually different, the alkali metal content being lower and the calcium content higher than in deposits from stoker-fired boilers. The sulfate content is of the same order in deposits from both types of boiler, but deposits from stoker-fired boilers are usually acidic while those from pulverized fuel boilers are usually alkaline.

The difference in the analyses is shown by results in Table I for deposits taken from high-temperature surfaces and classified as bonded by microscopic examination. These results, which are based on examination of 17 samples of deposits from pulverized fuel boilers and 20 samples from stoker-fired boilers, represent the average analyses of deposits from seven different stations.

In many cases the alkali-metal contents of the deposits from the pulverized fuel boilers were too low for them to be classified as alkali-bonded despite their appearance under the microscope. This is particularly well illustrated by the analyses of two samples of bonded deposit shown in Table II, one from the superheater of a pulverized fuel boiler and the other from the superheater of a stoker-fired boiler, both of which had been fired with the same coal (chlorine content about 0.9 per cent).

TABLE I—AVERAGE ANALYSIS OF BONDED DEPOSITS FROM SEVEN POWER STATIONS (WEIGHT PER CENT)

Type of Boiler	Pulverized-Fuel-Fired			Stoker-Fired			
Station No.	1	2	3	4	5	6	7
$(NaK)_2O$	3.9	1.3	0.4	12.2	14.9	9.1	28.4
CaO	11.8	8.5	16.0	3.3	2.4	1.5	2.2
SO_3	27.2	18.5	25.6	29.9	31.0	22.1	47.5
$(NaK)_2O$ / CaO	0.33	0.15	0.03	3.7	6.2	6.1	12.9

* Reprinted by permission from the March 1955 issue Vol. XXVIII, No. 170, p. 117–120, Journal of the Institute of Fuel, 18 Devonshire St., London W. 1.

† Fuel Research Station, Department of Scientific and Industrial Research.

[1] The Boiler Availability Committee is representative of the British Electricity Authority, the Water-tube Boilermakers' Association, the Fuel Research Station of the Department of Scientific and Industrial Research, and the British Coal Utilization Research Association.

[2] Numbers in parentheses refer to Bibliography at the back of the article.

TABLE II—ANALYSIS OF SUPERHEATER DEPOSITS (WEIGHT PER CENT)

Constituents	Pulverized-Fuel-Fired Boiler	Stoker-Fired Boiler
SiO_2	15.7	29.6
Fe_2O_3	3.4	4.9
Al_2O_3	8.6	15.6
P_2O_5	0.3	0.5
CaO	31.9	4.3
$(NaK)_2O$	4.2	20.9
SO_3	30.7	26.8

The possibility therefore arises that calcium sulfate may be acting as a bonding agent as well as sulfates of alkali metals, as originally suggested by Carlile, (3) and it appears from the analyses of some deposits that they are bonded almost entirely by calcium sulfate. Accordingly, it is suggested that deposits of this type be described as "calcium-bonded."

These deposits can be identified by the following method. A small sample of crushed deposit is boiled with distilled water and allowed to settle. A drop of the supernatant liquor is then placed on a microscope slide and the liquid slowly evaporated on a warm hot plate (2 to 3 minutes). The residue is examined microscopically using a magnification of 100 diameters. If the deposit is of the calcium-bonded type, clusters of distinctive needle-shaped crystals of calcium sulfate will form, as shown in Fig. 1. Under the conditions of the test, sulfates other than calcium do not give characteristic crystals.

In general, deposits from stoker-fired boilers give no crystals of calcium sulfate. Most deposits from pulverized fuel boilers give some crystals, but only calcium-bonded deposits give a large quantity of crystals.

Mechanism of Formation of Calcium-Bonded Deposits

The bonding agent in alkali-bonded deposits consists of alkali-metal sulfates derived from alkali-metal chlorides in the coal. It is not known whether deposit formation is initially due to the chloride or the sulfate; since both salts are readily fusible, it is probable that either can act as the initial bonding agent. However, calcium sulfate fuses at a relatively high temperature (m.p. 2370 F), and therefore cannot be the initial bonding agent in calcium-bonded deposits. The only calcium compound with a relatively low melting-point likely to occur in boiler flue gases and which would act as the initial bonding agent is the chloride (m.p. 1400 F). Calcium chloride is also a relatively volatile substance compared with sodium chloride, and deposit formation could therefore proceed by condensation of calcium chloride on the boiler heating surfaces. The condensed calcium chloride would provide a semi-molten matrix for ash particles, forming a bonded deposit, and the chloride would subsequently be converted to the sulfate by the action of the sulfur trioxide and sulfur dioxide in the flue gases.

Although calcium chloride is not found in deposits, the above theory suggests that calcium chloride should be found as such in boiler flue gases. This point has been investigated by taking dust samples from the flues of three pulverized fuel boilers. The dust above about 2 microns in size was precipitated in a small cyclone and the calcium chloride was extracted with ethyl alcohol and determined. The results are shown in Table III.

TABLE III—CALCIUM CHLORIDE CONTENT OF PULVERIZED-FUEL FLY-ASH

Chlorine in coal, per cent	0.94	0.37	0.32
Calcium chloride in fly-ash above about 2 microns, per cent	0.74	0.06	0.04

It appears that an appreciable amount of calcium chloride was present only in the flue gases from the boiler fired with coal of particularly high chlorine content; this was the only boiler of the three in which bonded deposits were formed.

It seems that the amount of calcium in the coal is not of great significance with respect to the formation of calcium chloride in boiler flue gases, since calcium-bonded deposits have been found in boilers fired with coals of both high and low lime content.

It seems possible that the calcium chloride found in the flue gases could originate in either of two ways: (i) It could be present in the coal and be vaporized during combustion. (ii) It could be formed in the flue gases themselves by interaction between hydrogen chloride and calcium carbonate or oxide.

These two possibilities will now be examined in detail.

It has been stated that most of the chlorine in British coals is present as chlorides of alkali metals (2). The nature of the chlorine in a number of coals, mostly from the East Midlands, has recently been further investigated. Ten samples of coal were ground to a size of 5 microns or less, and extracted with water. The

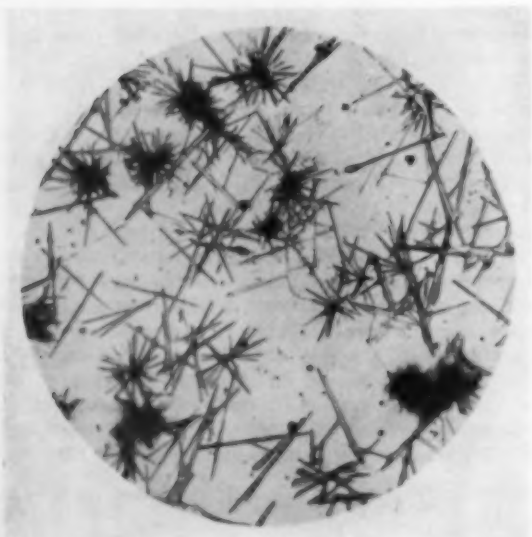

Fig. 1*—Calcium sulfate form clusters of distinctive needle-shape crystals which help identify this compound

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TABLE IV—ANALYSIS OF HIGH-CHLORINE COALS (WEIGHT PER CENT)

Coal	Na_2O Total	Na_2O w/s*	K_2O Total	K_2O w/s	CaO Total	CaO w/s	Cl Total	Cl w/s	Total S	SO_3 w/s
1	0.41	0.31	0.24	0.04	1.75	0.67	0.98	0.98	1.9	0.09
2	0.46	0.30	0.54	0.08	1.21	0.42	0.87	0.86	0.8	0.12
3	0.29	0.27	0.02	0.01	0.51	0.44	0.83	0.79	1.2	0.27
4	0.36	0.28	0.15	0.03	1.94	0.51	0.66	0.65	1.9	0.36
5	0.33	0.26	0.33	0.04	1.63	0.33	0.66	0.63	0.9	0.07
6	0.20	0.21	0.05	0.01	0.22	0.10	0.66	0.62	1.0	0.08
7	0.30	0.21	0.42	0.05	0.55	0.20	0.62	0.60	0.6	0.05
8	0.35	0.23	0.49	0.05	1.56	0.23	0.54	0.53	0.5	0.02
9	0.28	0.23	0.26	0.04	0.77	0.28	0.53	0.50	1.2	0.25
10	0.34	0.20	0.67	0.08	1.89	0.17	0.40	0.40	1.0	0.11

* w/s = water-soluble.

aqueous extract from the coal and the coal itself were then analysed for sodium, potassium, calcium, chlorine and sulfur. The sodium, potassium and calcium were determined with the flame photometer. The results are shown in Table IV, in which the coals are arranged in descending order of chlorine content.

It has previously been reported that more of the chlorine can be extracted by water from ultra-finely ground coals than from coals ground to the ordinary pulverized-fuel specification (4). The above results show that in many coals the chlorine can be extracted almost quantitatively after ultra-fine grinding.

The significance of the results can be more easily appreciated by expressing them in gram-equivalents per 1000 g. of coal. The results are shown in this way in Table V.

TABLE V—WATER-SOLUBLE MATERIAL IN HIGH-CHLORINE COALS (GRAM-EQUIVALENTS PER 1000 G. OF COAL)

Coal	Na^+	K^+	Ca^{++}	Cl^-	SO_4^{--}	Sum of cations	Sum of anions
1	0.100	0.009	0.239	0.276	0.022	0.348	0.298
2	0.097	0.017	0.150	0.242	0.030	0.264	0.272
3	0.087	0.002	0.157	0.223	0.067	0.246	0.290
4	0.090	0.006	0.182	0.183	0.090	0.278	0.273
5	0.084	0.009	0.118	0.177	0.018	0.211	0.195
6	0.068	0.002	0.036	0.175	0.020	0.100	0.195
7	0.068	0.011	0.071	0.169	0.013	0.150	0.182
8	0.074	0.011	0.082	0.152	0.005	0.167	0.157
9	0.074	0.009	0.100	0.149	0.063	0.183	0.212
10	0.065	0.017	0.061	0.113	0.028	0.143	0.141

It can be seen from Table V that the major part of the chlorine is found in the aqueous extract as sodium and calcium chlorides. The amount of soluble potassium and soluble sulfate is relatively small. In most of the coals there is a reasonable balance between the anions and cations in the aqueous extract, the differences presumably being due to the presence of other ions which were not determined, e.g., magnesium.

These results do not establish that calcium chloride is present as such in coals of high chlorine content, but they suggest that it may be present and that the possibility of calcium chloride being vaporized during combustion cannot be ignored.

In addition to the possibility of calcium chloride being vaporized as such from the fuel, there is also the possibility of its being formed by reactions in the flue gases. In most coals, a considerable portion of the calcium is present as adventitious calcium carbonate (ankerites). Pulverizing the coal will result in the separation of discrete particles of calcium carbonate from the coal substance, and during combustion these particles of carbonate may well be expected to dissociate, giving rise to reactive particles of lime in the flue gases. At some temperature in the boiler system the lime particles will react with acidic constituents of the flue gases, the probable products of the reaction at high temperatures being calcium chloride and calcium sulphate.

It can be shown from thermodynamic considerations that calcium chloride in the liquid or solid phase will tend to react with the sulfur dioxide in flue gases at all temperatures, giving calcium sulfate. Also, at temperatures above about 1100 to 1400 F. (depending on the chlorine content of the coal), calcium chloride in the presence of flue gas will tend to react with water vapor to give lime and HCl, whereas calcium sulfate will be stable at temperatures up to about 2000 F.

It might appear from these thermodynamic considerations that calcium chloride could not be formed at all in boiler flue gases; however, the thermodynamic data refer only to equilibrium conditions, and if the rate of formation of chloride were rapid compared with its subsequent conversion to form sulfate, the chloride could exist in conditions under which it is thermodynamically unstable. Further, calcium chloride, in view of its considerable volatility, might be stable in the vapor phase.

Laboratory experiments have been made to study the possibility of the formation of calcium chloride in flue gases at temperatures similar to those in the superheaters of power-station boilers.

The experiments were carried out by burning kerosine, containing calcium naphthenate, in an atomizing burner. The flue gases contained finely divided lime particles thought to be similar to those formed during the combustion of pulverized coal. Sulfur and chlorine were added to the fuel as carbon disulfide and chlorobenzene to give concentrations of SO_2 and HCl normally found in boiler flue gases. Samples of the solid material in the flue gases were from a measured volume of gas drawn through a sintered glass filter heated to prevent dewing.

A series of experiments was run in which the sulfur content of the kerosine was varied from 0.5 to 6.0 per cent, and the chlorine content from 0.3 to 1.0 per cent. The calcium content was varied from 0.1 to 0.5 per cent, but in most runs was kept at 0.1 per cent. In each run, the amounts of calcium sulfate and calcium chloride formed were determined by analysis of the material on the sintered glass filter. Sulfate was determined turbidimetrically, and chloride by silver nitrate titration.

It was found that the lime formed in the flame of the burner reacted quite readily with SO_2 and HCl in the flue gases to form calcium sulfate and calcium chloride and that the relative amounts formed depended on the amounts of S and Cl in the oil. The composition of the flue dust is best given by the ratio Ca (as sulfate)/Ca (as chloride) and this was found to bear a close relationship to the ratio S:Cl in the fuel, as is shown by the graph in Fig. 2. Reference to this graph shows that the ratio of sulfate to chloride increases rapidly with the ratio S:Cl in the oil. The amounts of sulfate and chloride formed are approximately equal when the ratio S:Cl is about 0.5:1, but at a S:Cl ratio of 3:1 little more than 10 per cent of the lime is converted to chloride, and at a S:Cl ratio of about 5:1 the formation of chloride is almost completely suppressed.

It is therefore concluded that calcium chloride can be formed in boiler flue gases by reaction between lime and HCl, but that with a S:Cl ratio of more than about 2 or 3 to 1 the proportion of chloride formed will be small.

Discussion

The most important conclusion from the present investigation is that although the bonded deposits formed by the combustion of coal of high chlorine content in stoker-fired boilers are largely due to alkali-metal chlorides, the bonded deposits formed in boilers fired with pulverized coal of high chlorine content may often be due to calcium chloride. A definitive explanation cannot be put forward at the moment for the difference in behavior of the two types of boiler, but it seems probable that the vaporization of alkali-metal chlorides is much less in pulverized fuel boilers than in stoker-fired boilers. This would explain why alkali-bonded deposits are far more common in stoker-fired boilers than in

pulverized fuel boilers. The absence of calcium-bonded deposits in stoker-fired boilers may be due to most of the calcium chloride in the flue gases being formed from lime particles and HCl; if this were so, significant quantities of calcium chloride would not be formed in stoker-fired boilers, since only a small proportion of the lime would be separated from the coal and carried off the grate. It therefore seems likely that if calcium chloride is present as such in the coal very little is vaporized during combustion either in stoker firing or pulverized-fuel firing; this may be because any calcium chloride present reacts with ash constituents during combustion to give non-volatile calcium compounds and HCl.

Acknowledgments

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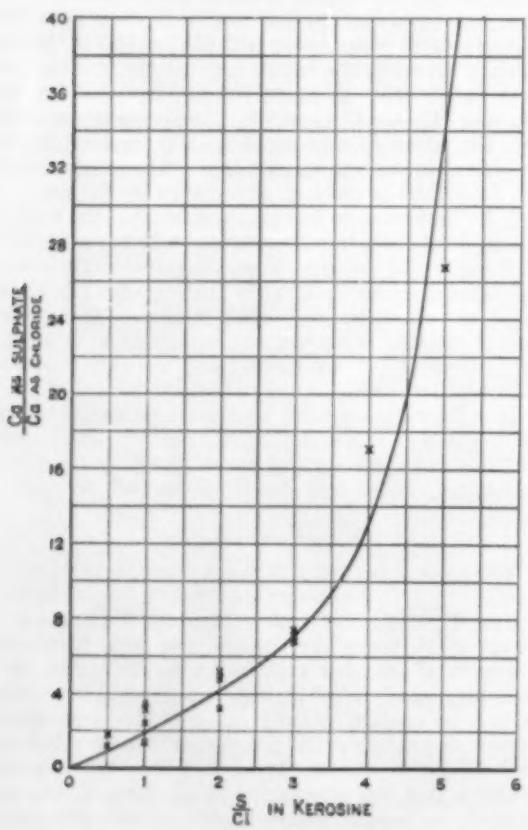

Fig. 2—Curve plots the variation in the composition of flue dust with the ratio of S to Cl in the kerosine

*Fuel Resources and Utilization in Present Day Germany**

MORE than 95 per cent of Western Germany's energy supply from indigenous fuels is based on coal and brown coal. The problems these fuels present for steam generation are discussed below. In addition the general field of fuel utilization has several outstanding features worthy of mention. Rhurgas A-C has developed a gas grid to distribute surplus coke-oven gas from the steelworks and producer gas made from low-grade coals. Combined heat and power supplies based on back-pressure steam for process are another example. In this latter case there is at least one coal mining company that has achieved complete integration of coal production and consumption with coking plants, chemical works and nitrogen factories involved.

The general trend in Western Germany for steam boiler furnaces, as in most other countries, has been towards pulverized-coal burning, but—differing from other countries—with a preference for high-rated slag-tap furnaces; the salient point in this development has been the ever-present problem of air pollution, the difficulty of disposing of fly-ash as obtained in dust collectors and electrostatic precipitators, and the possibility of transforming the residual into a salable product or at least modifying.

After a sufficient time has elapsed to enable practical experience to be obtained with these new slag-tap furnaces and with the burning of high-ash low-grade fuels, the main point of discussion will be the problem of boiler availability and deposits in the boiler, superheater, economizer and air heater.

It has been the general experience that intensifying the combustion by increased temperatures and improved physical conditions of mixing and burning and subsequent cooling to at least 1,740 F gas-exit temperature, increases the rate, efficiency and availability of the boiler.

Slag-tap furnaces are operating at rates of high release of 170,000 to 560,000 Btu per c ft per hr but usually require cooling chambers of such a volume that the overall rates of heat release are of the same order of magnitude as those of high-rated dry-bottom furnaces. The main advantage, however, which renders slag-tap furnaces so much more attractive, is the retaining of a large part of the mineral matter, and consequent reduction of the dust loading entering the precipitator, as well as the ability to melt additional quantities of fly-ash In some cases remelting of fly-ash from neighboring non-slagging boilers is also practiced successfully.

With further increase of the temperature in the combustion chamber, deposit formation diminishes until a certain point is passed when apparently deposit starts to increase and change in character. These experiences have stimulated a program of research to cover: (1) identification of the mineral matter of coal by mineralogical (not chemical) analysis; (2) study of the behavior of mineral matter when heated excessively quickly; (3) reaction products at high temperatures and heating rates.

It has become more and more evident that previous methods of analyzing mineral matter at low temperatures, under strictly oxidizing conditions and at low rates of heating, do not stimulate furnace conditions or predict ash behavior in full-scale furnaces.

* Abstracted from the paper "The Fuel and Power Resources of Germany and their Utilization," by Dr. W. Gumz, Coal Utilization Dept., Essen, Germany before the Institute of Fuel, London, England, March, 10, 1955.

Commercial and International Developments in Atomic Energy

MORE than one thousand persons were registered for the technical discussions that were a part of the Third Annual Meeting of the Atomic Industrial Forum held at the Sheraton Park Hotel in Washington, D. C., September 27–29. The theme of this meeting, "Commercial and International Developments in Atomic Energy," was carried through in 14 separate panel discussions on such topics as power reactors, marketing atomic products and services, reactor safety, gearing up to atomic activities, AEC responsibilities in commercial developments, and fuels and source materials.

Paralleling the Third Annual Forum meeting was the First U. S. Trade Fair of the Atomic Industry at which more than 70 American and foreign industrial organizations had exhibits. Attendance at this highly successful trade fair, which featured many exhibits that had previously been shown at the Geneva "Peaceful Uses of Atomic Energy" conference, amounted to several thousand representatives from government and industry.

At the annual banquet **Lewis L. Strauss,** chairman of the U. S. Atomic Energy Commission, made an address in which he took a reminiscent look at the recent Geneva Conference on the Peaceful Uses of Atomic Energy. He observed that of the 1110 papers presented to the conference, 48.2 per cent were submitted by the United States. The research reactor, built at Oak Ridge National Laboratory and flown to Geneva, quickly acquired the name of "The Tennessee Chalet" and was visited by more than 63,000 persons during the two weeks of the conference.

According to Admiral Strauss, "Soviet written reports to the Conference showed careful preparation and a considerable amount of detail. But it became apparent early in the proceedings that in answering the questions of delegates, they were not prepared to engage in the same degree of frankness as other delegations. The Russian delegation, of whom some 79 were technicians, impressed our people as generally competent and in some instances, as exceptional men. We have no way of knowing whether it was their first team, but as one of our people said, 'they were good enough to be a first team.'

"It is the general impression among the members of our delegation that on the basis of Geneva, we are well ahead of other nations—all other nations—in both the scope and the state of our technology in using atomic energy for peaceful purposes. This however, was to be expected since we appear to have a considerably larger program than any other country and we have been engaged upon it for a longer time.

"In this connection, it is interesting to note, however, that at least one of the Russian papers presented at the Conference bore the date of 1943, indicating that they had been seriously concerned with the subject for a longer time than many of us realize. While what the Russians revealed at Geneva did not contain anything new or startling, it did give some insight into their working methods and into the caliber of their research. On the basis of their rôle at Geneva they appeared stronger in basic research than in its practical applications.

"The fact that we appear to be ahead in the peaceful applications of atomic energy—perhaps by a scant few years—certainly offers no justification for complacency. To the contrary, the situation must be regarded as a serious challenge. The Soviets have not outstripped nor equalled us

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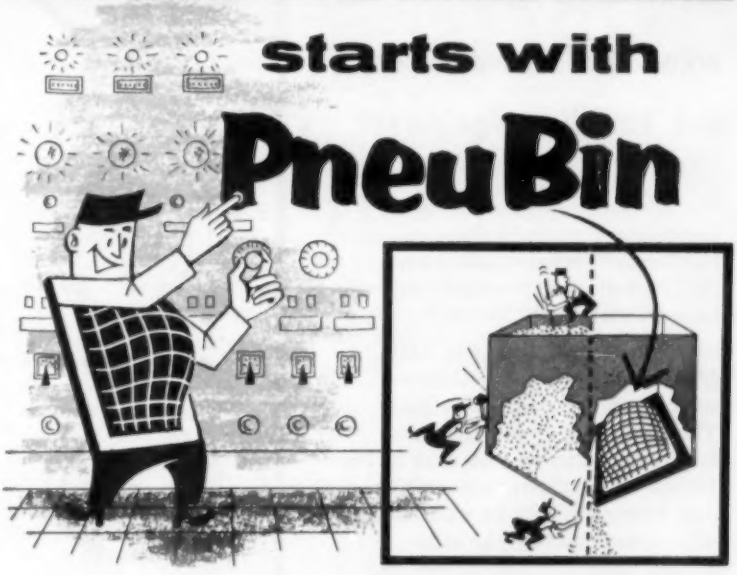

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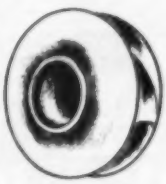

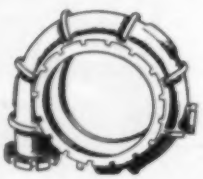

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in any peaceful application, but at the same time—and this is important—we did not show anything at Geneva which they cannot have in a few years, given the talent and zeal which we believe them to possess.

"Too many of us have been thinking of the Russians, either by education or temperament, as not quite equal to us in the technological sense. Despite the many things wrong with their political system from our point of view, let us not fall into the easy attitude of assuming that they cannot compete with us in mastering atomic energy. The early date at which they produced nuclear weapons should be a constant reminder of the fallacy and danger of such an attitude on our part. We can never let down our research without letting down our guard at the same moment."

Economics of Nuclear Power

Jules Wayne of the U. S. Department of State presented his unofficial observations in a paper entitled "Post Geneva Economic Aspects of Nuclear Power." He pointed out that capital costs of large central nuclear power stations will exceed those of conventional steam stations by about 50 to 100 per cent and therefore a portion or all of the potential fuel savings may be offset by additional overhead charges. The hope for atomic energy lies in the expectation that a declining curve for the capital costs will cross a rising curve of conventional fuel costs. The cost trends of past inventions substantiate the expectation of falling capital costs for atomic power and this expectation is further strengthened by the predictions of the scientists at Geneva.

With respect to underdeveloped areas Mr. Wayne noted that a fairly typical cost of power shortages and high power costs is lack of capital for investment in power facilities. In some cases, this lack of capital prevents the replacement of old, small, inefficient plants with modern efficient thermal stations. Cost savings possible through such replacement far exceeds in many cases any possible savings that might be attained by the replacement of modern thermal stations with nuclear stations. In other cases lack of capital has prevented or delayed the exploitation of native low-cost energy resources. Many under-

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The very fact of underdevelopment in many cases involves small or intermittent demands for power which results in the high overhead charges mentioned in the example above. Because of the higher capital cost involved, nuclear power is more vulnerable to low operating rates than is conventional thermal power.

In concluding Mr. Wayne stated that the outlook in underdeveloped areas in the foreseeable future does not warrant the present optimism. Moreover, even if the underdeveloped areas afford larger outlets for nuclear power than is now indicated nuclear power will not generate an industrial revolution in backward areas as many popular writings suggest. Electric power is a necessary factor for economic growth but represents only a relatively small share of the total costs of most industries. In the U. S. the entire cost of electricity including transmission and distribution charges in relation to the value added by manufacture average only 1.7 per cent in 1947. Many other factors, particularly the availability of capital, technical know-how and the degree of political stability are more important than the cost of power for economic growth. Unless the economic aspects of nuclear power are more realistically evaluated many countries may find they are employing scarce technical and scientific personnel and capital for purposes which offer only very remote advantages.

Commonwealth Edison Reactor

In a paper entitled "Teamwork for Progress," **O. B. Falls,** manager of the Marketing Section of the Atomic Power Equipment Department of the General Electric Co., outlined the background of the nuclear power plant project of the Nuclear Power Group in collaboration with the General Electric Co. Commonwealth Edison Co. of Chicago will own and operate the plant as an integrated part of their system and will pay 30 million dollars toward the 45 million dollar contract price. The remainder of the contract cost will be paid as a research and development expense over a period of five years by the research group which is comprised of American Gas and Electric Corp., Bechtel Corp., Pacific Gas and Electric Co., Union Electric Co. of Missouri, Central Illinois Light Co., Illinois Power Co., Kansas City Power and Light Co., and Commonwealth Edison Co. This 15 million dollar research and development expense will be shared by the eight member companies and paid over a period of five years. These companies, other

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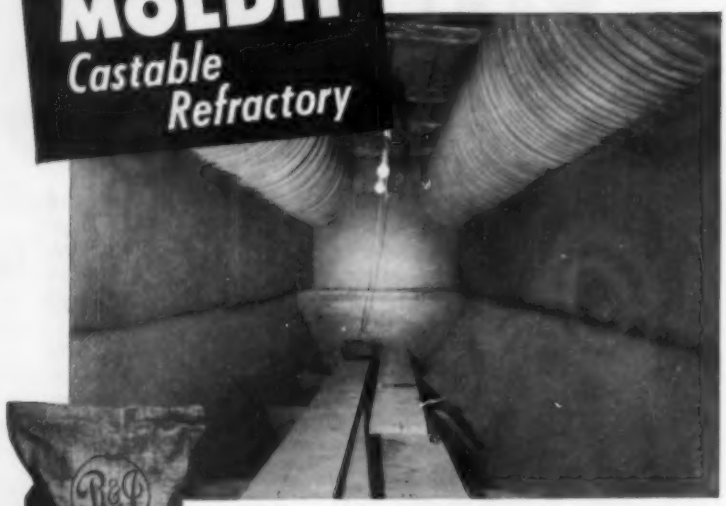

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than Commonwealth Edison, will have no ownership in the plant but will get technical information, experience and training, which can be obtained only from day-to-day participation in designing, building and operating a full-scale plant. Personnel from all of the utility companies will have the opportunity of participation in the engineering design phases under the auspices of Bechtel Corp. and the Co.

As has been announced earlier the nuclear power plant, which will have a capability of 180,000 kw will employ a dual-cycle boiling reactor designed by G.E., some details of which were outlined in an article on pages 55–57 in June 1955 COMBUSTION.

Factors leading to the site location of the Dresden Station, as the reactor plant is to be called, were similar to those which would influence choice of a conventional utility steam station. Because of the lower thermal efficiency deriving from lower initial steam conditions and the greater cooling requirements of the present design of the reactor, an adequate supply of cooling water is an even more important consideration in site selection than is the case with conventional plants.

Two things made site selection simpler for this nuclear power plant than for others. These are the inherent safety of the reactor which automatically shuts down in case of an accident, and plans to contain the entire system—reactor, control room and turbine-generator—in a huge steel sphere.

Consolidated Edison Reactor

W. C. Gumprich, head of reactor design for the Atomic Energy Division of The Babcock & Wilcox Co. provided some details for the 236,000-kw nuclear steam generating plant to be known as the Indian Point Station of The Consolidated Edison Co. of New York. Steam consumption in the plant, which includes an oil-fired superheater to deliver design steam temperature, is 1,900,000 lb per hr at 370 psia and 1000 F. Nuclear fuel provides energy at a rate of 500,000 kw and oil provides an equivalent of an additional 200,000 kw, giving a gross plant efficiency of approximately 34 per cent.

The reactor is the internal thorium converter type, fueled with highly enriched U-235, moderated and cooled with pressurized light water. The active portion of the reactor core is a cylinder 6 ft in height and 6 ft in mean diameter. It is composed of square assemblies of fuel and fertile plates arranged with coolant flow channels between plates. The fertile plates consist of thorium metal clad with Zircaloy; the fuel plates consist of a highly enriched Zircaloy alloy clad

with Zircaloy. The separation of fissionable and fertile material in this manner makes possible relatively lengthy irradiation of fuel assemblies with moderate burnup in the thorium, resulting in more efficient utilization of both the inital U-235 charge and the U-233 produced in the thorium. Thorium was chosen as the fertile material on the basis of favorable long-term reactivity characteristics and relatively good structural resistance to fission damage.

The composition of the core is determined by the requirements of heat transfer, structural integrity, excess reactivity and need for an adequate negative temperature coefficient. With about 55 per cent of the core volume required for coolant flow and an inventory of about 8100 kilograms of thorium, about 210 kilograms of fully enriched U-235 provide sufficient excess fuel to accommodate the various reactivity changes. With this loading the initial thermal neutron flux at 500,000 kw is approximately 8 $\times 10^{13}$ n/cm^{2}sec.

The thermal design of the reactor is based upon a limiting maximum fuel plate surface temperature of about 600 F and the use of a working pressure high enough to prevent surface boiling at full power operation. These conditions are fulfilled at full load by the circulation of 120,000 gallons of water per minute at a pressure of 1500 psia; the reactor inlet and outlet water temperatures are 480 F and 510 F, respectively. These conditions are adequate for the economical generation of saturated steam at 420 psia.

The reactor pressure vessel is a cylindrical shell 9 ft 9 in. I.D. with walls 6$^7/_8$ in. minimum thickness of Sa-212 Grade B plate with inner face clad with 0.109 in. thick spot-welded cladding of Type 304 stainless steel. The vessel will be designed and fabricated in accordance with the ASME Unfired Pressure Vessel Code for a design pressure of 1800 psi at 550 F.

The primary coolant system transmits sub-cooled water from the reactor to four boilers, each being capable of transferring one-fourth of the total reactor power to the steam system. Each boiler loop consists of the boiler, two parallel 15,000-gpm pumps with check valves and 24-in. 304 stainless steel pipes between the boiler and the reactor, and 24-in. remote operated stop valve.

The reactor is located below the remainder of the system so that draining a boiler loop will not uncover the core. The pressurizer is located at the high point of the system to facilitate venting, filling, and pressure control. All possible air entrapment volumes will be vented and with the exception of

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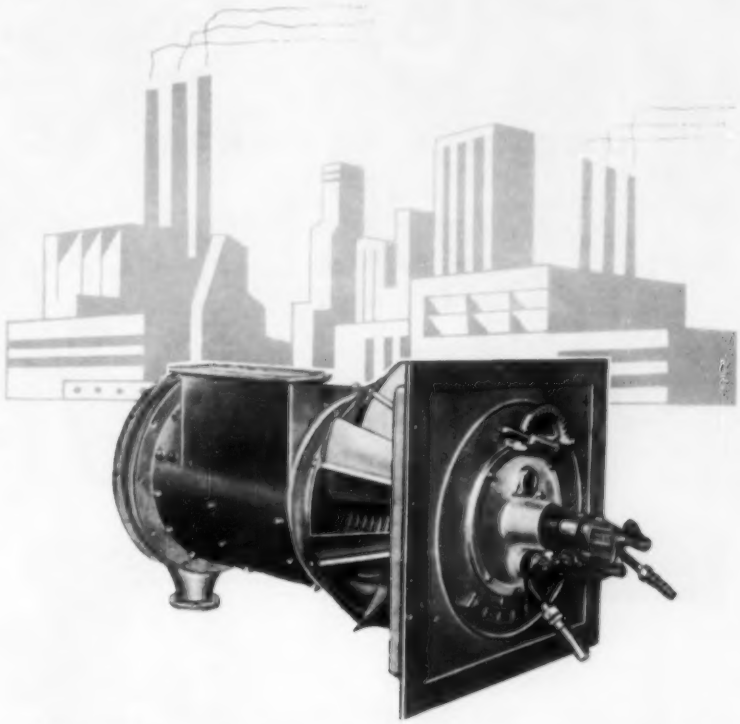

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the reactor, drain lines will be connected to any potential water trap.

The four boilers transfer 500,000 kw of reactor heat while generating a throttle flow of 472,500 lb of saturated steam per boiler per hour at 420 psia from feedwater at a temperature of 332 F. During normal reactor cooling cycles, as well as emergency cooling periods, these units will serve as a heat sink, thereby removing excess heat from the system in an orderly fashion at a rate which will adequately cool the reactor and primary system.

Each unit includes a U-type heat exchanger with primary circuit flow through the tubes and steam generation on the shell side of the tube surface. A steam drum is located above the heat exchanger surface sufficiently elevated to create natural circulation within the unit. Adequate downcomer and riser pipes are included to permit natural circulation. To insure dry steam at the main steam outlet, cyclone separators, complete with plate-type scrubbers, are installed in the steam drum.

A total of eight primary coolant pumps is provided, two pumps operating in parallel in each circuit. For normal operation the pumps operate at constant speed for all reactor loads. However, one pump in each loop can be operated at low speed from an emergency power supply.

Sodium-Graphite Reactor

The proposed sodium-graphite reactor for the Consumers Public Power District, having an electrical output of 75,000 kw was described by **Chauncey Starr,** vice president, Nuclear Engineering & Manufacturing, North American Aviation, Inc. This project of reactor design was chosen because of (1) immediate technical feasibility and (2) confidence that improvement in sodium technology will advance sufficiently to make this type of reactor ultimately economic. Among the advantages of sodium-graphite power reactor are the fact that high steam temperatures are possible (900 F present and ultimately 1200 F or higher), and almost any type of nuclear fuel can be used. The proposed reactor will have throttle steam conditions of 800 psig, 825 F. Mr. Starr pointed out the need for commercially available instruments for use in liquid metal systems and expressed the belief that increasing commercial developments along these lines will afford considerable reduction in the capital costs.

Army Package Power Reactor

Kenneth Kasschau, manager of engineering for the atomic energy activities of Alco Products, described the power reactor now being designed by

his company. The reactor will be operated at the specified 10-mw power level and will have a net electrical output of 1825 kw. Conservative design has been employed throughout and the end objective of remote installation has been borne in mind. The steam generator which requires a 33° deg F temperature difference to produce the superheated steam is vertically mounted so that thermal convection will provide emergency cooling. An iron water shield is provided which affords considerable weight saving if the aggregate for a concrete shield is lacking at a remote site. The main support member of the reactor vessel is the inner wall of the shield tank. This support in combination with the vertical type steam generator allows for very short pipe connections, and leaves essentially no thermal expansion stresses in the pipe. A double-walled steel shell, 32 ft in diameter and 60 ft high with 2 ft of concrete between the linings, provides containment against nuclear accidents. When the reactor is refueled, spent elements may be removed under water to a deep water-filled storage pit outside the container.

With the reactor operating at its designed level and a back pressure of 1.5 in. of Hg, the net station heat rate will be 17,800 Btu per kwhr at a net output of 1925 kw. With a back pressure of 2.5 in. of Hg the net station heat rate becomes 18,800 Btu per kwhr at a net output of 1825 kw.

The reactor is 20 in. square but with the corners omitted in order that the structure can approximate a cylinder somewhat more closely. Since the fuel elements are $2^{3}/_{4}$ in. square, there is space for forty-five elements, forty of which are for actual fuel elements and five of them are for control rods. These fuel elements are 22 in. in active length, and, with end boxes for support, total nearly 3 ft in overall length. They are held in position by a top and bottom grid, both of which are supported from a diaphragm within the thermal shield, which is in turn supported by an internal flange in the upper portion of the pressure vessel.

The core is contained within a reactor vessel 4 ft in diameter and 8 ft 5 in. high. Cooling water is introduced immediately below the diaphragm, which supports the reactor and serves to direct the water to the entrance plenum chamber at the bottom of the reactor vessel. From the bottom, the water flows upward through the fuel elements to the exit plenum chamber, from which the exit nozzle leads the water to the steam generator.

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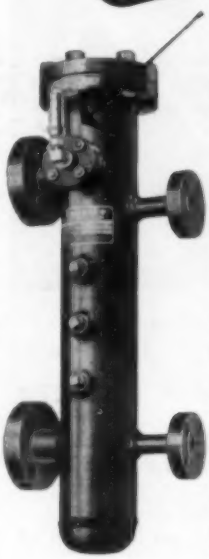

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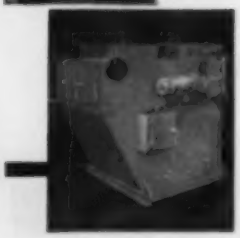

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MATERIALS HANDLING BY WEIGHT SINCE 1902

the reactor, the steam generator, and two circulating pumps. The primary circuit is maintained at 1200 psia to preclude boiling (saturation temperature 568 F). Water leaves the reactor at 450 F—and enters the steam generator, passing thru U-tubes which are surrounded by water in the secondary circuit. The primary water is cooled to about 431 F at full load, and on leaving the steam generator is returned to the reactor by means of a motor-driven pump.

The primary coolant circuit includes two canned-rotor type motor-driven coolant pumps, only one of which is required for full-load operation. One hundred per cent stand-by is provided for by automatic start-up of the stand-by pump in event of electrical failure of the operating unit.

Steam is formed in the steam generator shell at 200 psia (382 F saturation temperature) at full load. At the normal heat transfer rate in the steam generator, the steam is superheated 25 deg F to reduce condensation in the last turbine stages. At decreasing loads, due to the nearly constant primary coolant inlet temperature to the steam generator, the saturation temperature on the secondary steam side will approach 450 F, so that at no load, steam will be generated at nearly 425 psia.

Reactor Fuel Elements

In a paper entitled "Industrialization of the Nuclear Fuel & Component Business" **Stanley B. Roboff,** manager, Industrial Coordination, Atomic Energy Division of Sylvania Electric Products, Inc., reported that his company reached the following conclusions:

1. That for the next 5 to 10 years, and possibly longer, it will be necessary for our company to invest considerable capital into new and unique facilities for the development, manufacture and recovery of nuclear fuels and for the manufacture of other special critical reactor materials and reactor components.

2. That we must locate our facilities strategically so that a fuel manufacturing and reprocessing plan can serve a large number and various types of reactors. As we see it now, such facilities may have to be located in selected areas throughout the country in order that the greatest possible processing efficiency can be combined with sensible logistic requirements.

3. That it will be necessary for us to invest considerable sums of our own money into the development of economical processes for the recovery and reprocessing of fuels.

4. That we must be prepared, to draw upon the most advanced engi-

neering and processing techniques to solve the complex problems associated with fuel and spent fuel processing.

Book Review

Principles of Engineering Thermodynamics (Second Edition)

By P. J. Kiefer, G. F. Kinney and M. C. Stuart

John Wiley & Sons, 539 pages, $7.75

Thermodynamics

By J. F. Lee and F. W. Sears

Addison-Wesley, 543 pages, $7.50

Thermodynamics

By R. L. Sweigert and M. J. Goglia

Ronald Press, 355 pages, $6.50

These three books are intended primarily for use as texts during the third year of engineering education. While all three are intended to furnish a sound background in the fundamentals of thermodynamics, the approaches to this common goal differ in a number of respects. From a quantitative standpoint, the books may be compared as follows:

Kiefer, Kinney and Stuart—17 chapters and approximately 235 numbered equations

Lee and Sears—14 chapters plus 6 appendices and approximately 640 numbered equations

Sweigert and Goglia—10 chapters plus two appendices and approximately 155 numbered equations

Subject matter in Kiefer, Kinney and Stuart is divided into four parts: classification and accounting of energy, availability of energy, properties of fluids and engineering applications.

In Lee and Sears, the first seven chapters are concerned with the first and second laws of thermodynamics and their consequences. The following two chapters, fluid flow and heat transfer, are intended to illustrate the use of thermodynamic principles and to set forth some of their limitations. In the concluding five chapters the thermodynamic approach is used to discuss mixtures, vapor power cycles, refrigeration and internal-combustion-engine process, and reactive systems.

The first three chapters of Sweigert and Goglia deal with the first and second laws of thermodynamics. The text then considers the perfect gas, including gas dynamics, mixtures, the relationship of thermodynamics to chemistry and specific thermodynamic applications.

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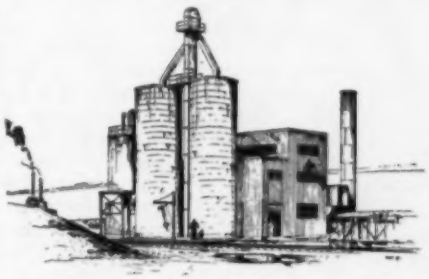
The Fairmont Coal Bureau has made available to consulting engineers and equipment manufacturers a TYPICAL DESIGN for the small industrial steam plant. Prepared as a guide to good engineering it achieves maximum economy of investment and engineering costs, while featuring:



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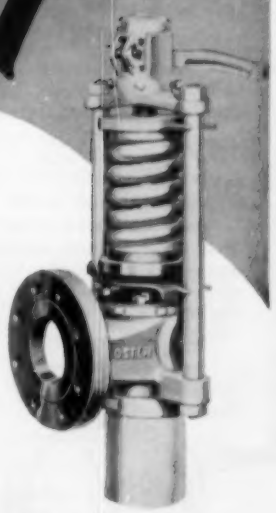

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In comparing the three texts it is well to keep in mind their merits from the standpoints of (1) value to the student at the time thermodynamics is taught and (2) long-term value of the text as an engineering reference work. Those teaching thermodynamics will, of course, evaluate the texts with respect to pedagogical soundness and the manner into which they fit specific engineering curriculum requirements.

Sweigert and Goglia have presented primarily only that material which may be expected to be taught during the junior year of engineering college. In their preface, they make the following statement: "We have considered the laws of learning in our arrangement of the material and believe that it achieves validity because it discusses thermodynamics on a level than can result in real mastery by the third-year student. The presentation makes use of information and ideas which are already clearly known to the student, introduces real examples for motivation, proceeds to a theoretical discussion which substantiates the motivation, and continually challenges the student to examine data and principles applicable to the new situations which the text sets before him." These worthy objectives appear to have been met in this rather concise presentation of undergraduate topics in thermodynamics.

The text by Lee and Sears is representative of the trend in engineering education to teach engineering science on a more rigorous mathematical basis. Its approach and generalized subject matter are sufficiently broad to make the text adaptable for physics and chemistry majors as well as student engineers. More material is included than can be covered adequately in a two-semester course, and this adds to the long-term reference value of the text, particularly for those who become involved in the more analytical phases of design or in research. As has become the tradition in Addison-Wesley books, the illustrations are of superior quality and include a number of excellent three-dimensional representations of state changes.

In the Second Edition, Kiefer, Kinney and Stuart have retained the features that have resulted in the widespread adoption of this text over a period of nearly twenty-five years. This is not a generalized text, as is the case with the other two being reviewed, but is avowedly related to those aspects of thermodynamics which are required in the design and operation of power machines. As the authors state in the preface "The emphasis is on the principles of engineering thermodynamics, endeavoring to implant a recognition both of the ideal capabilities and of the inherent limitations of power-plant and similar equipment."

One of the major contributions of the First Edition of Kiefer and Stuart was the emphasis upon basic physical concepts of thermodynamics, as distinguished from mathematical manipulation of equations without comprehension of the nature of properties and processes. It must be a source of some satisfaction to the authors to note the current widespread acceptance of what they considered features in which their original material differed from conventional practice in the teaching of thermodynamics as about 1930.

From the standpoint of facilitating learning, it is to be regretted that the new edition of Kiefer, Kinney and Stuart does not retain the practice of making important principles conspicuous by the use of bold-face type and the inclusion of concise summaries, along with review questions and topics, at the end of each chapter. These changes, however, do not detract from the merits of the new and enlarged edition which should find widespread use in institutions providing a course in thermodynamics specifically adapted to the needs of mechanical engineering students. As for the reference value of the text, anyone who has observed the personal libraries of mechanical engineers graduated in the last two decades will be aware that Kiefer, Kinney and Stuart is likely to remain a frequently consulted reference text.

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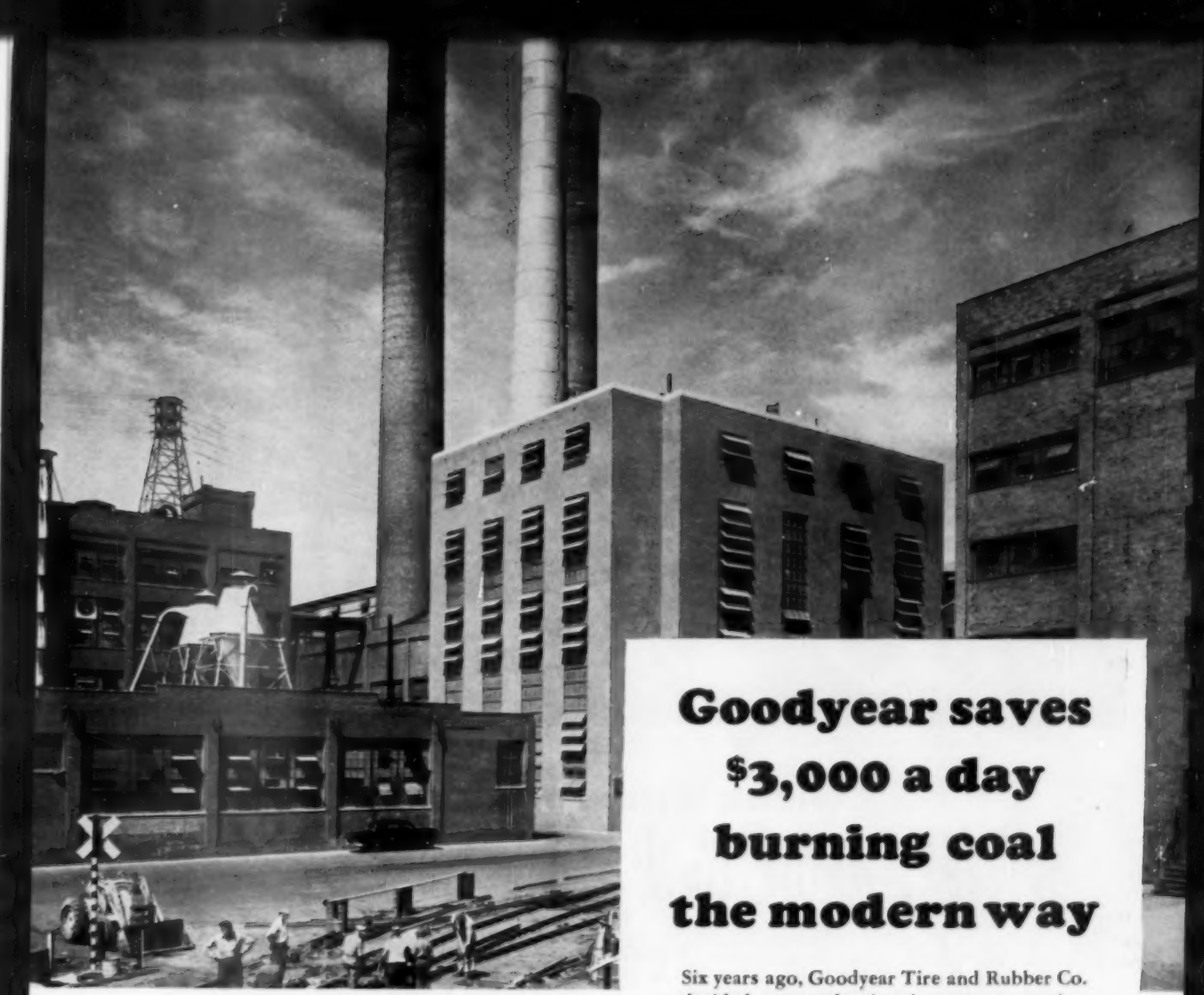

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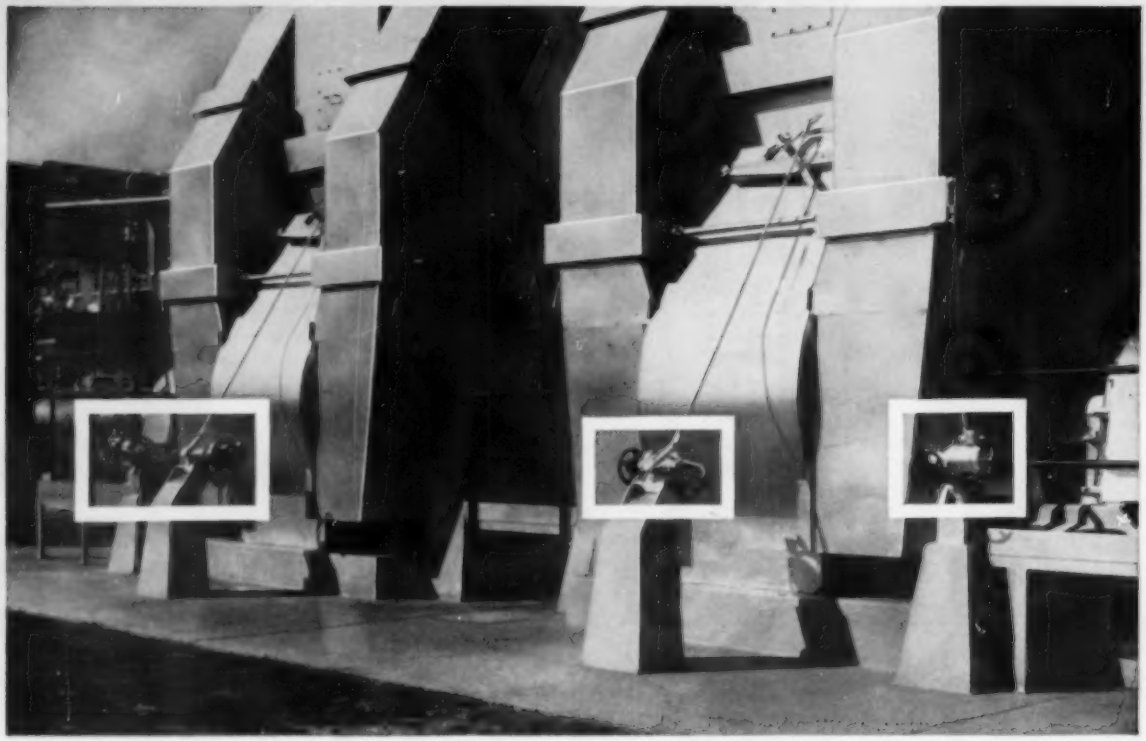

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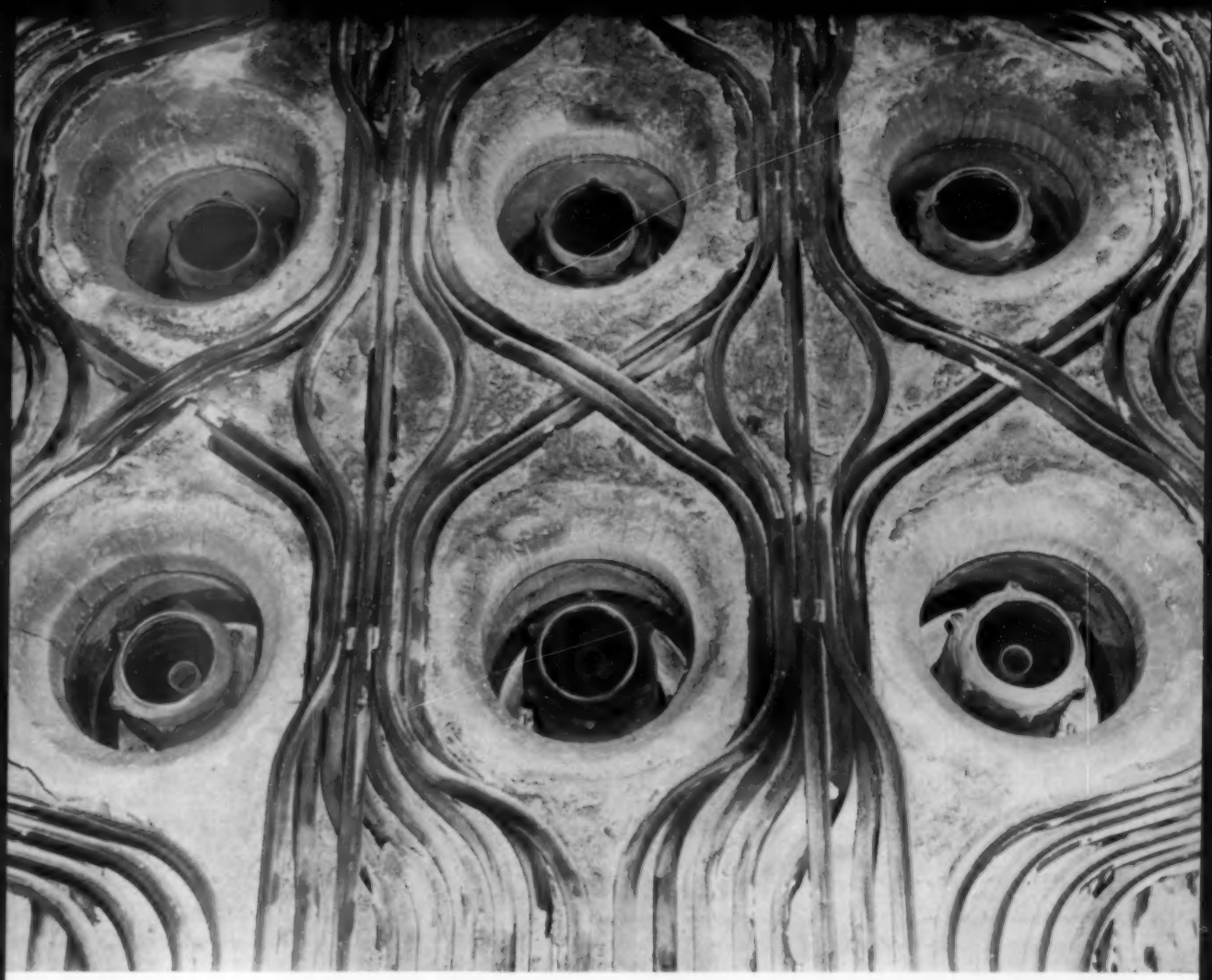

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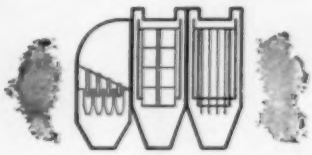

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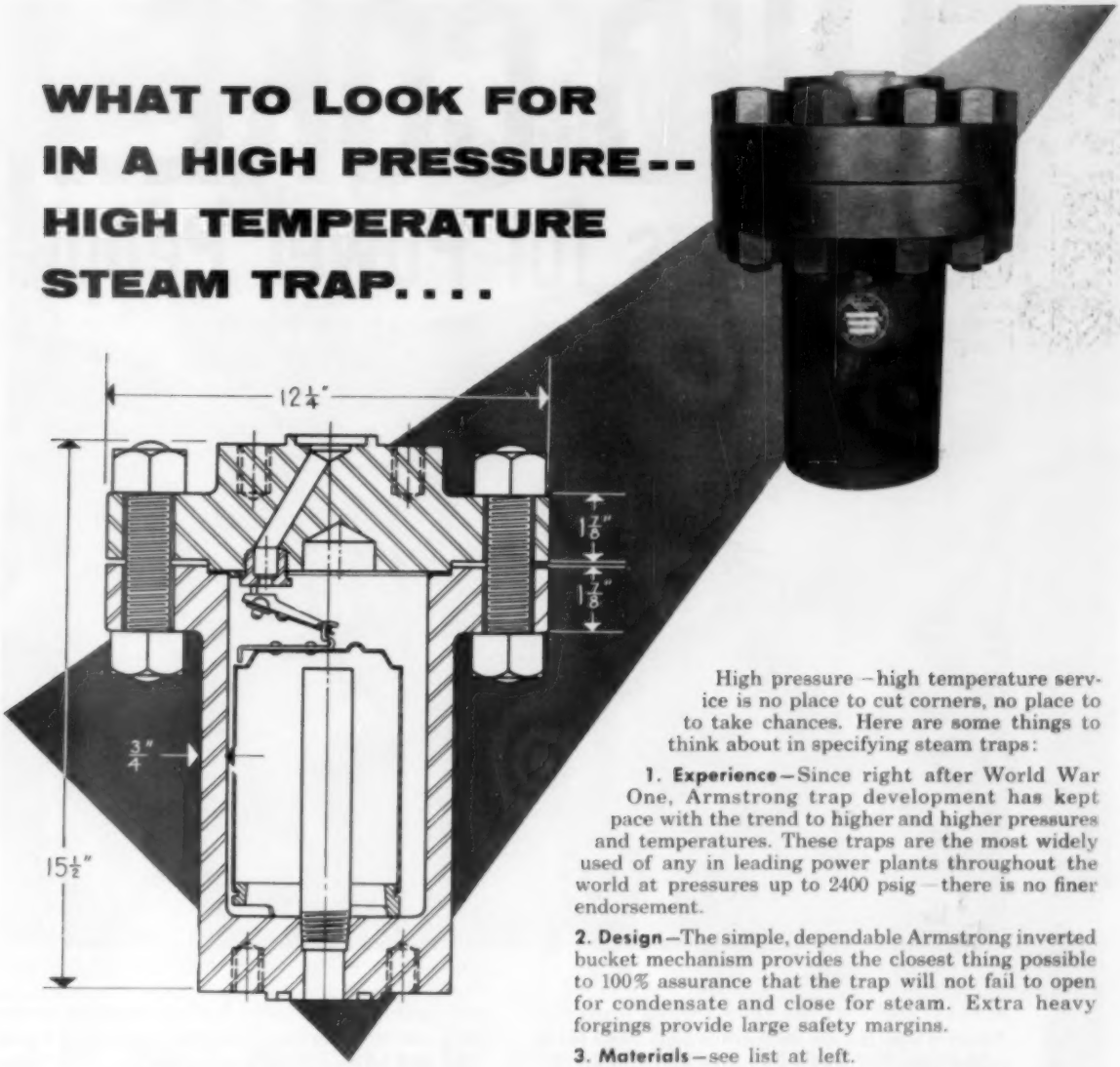

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Up to 2500 psi, above 900°	ASTM Spec. F-5 chrome moly steel
VALVE AND SEAT	Type 440 chrome steel, heat treated, standard. Stellite available.
LEVER MECHANISM	Stainless steel
BUCKET	Stainless steel
BOLTS	Class C high tensile, high temperature bolting material—125,000 min. tensile.
NUTS	Hex, semi-finish, heat treated for high pressure, high temperature service.
GASKET	Compressed graphited asbestos
INLET TUBE	Wrought iron

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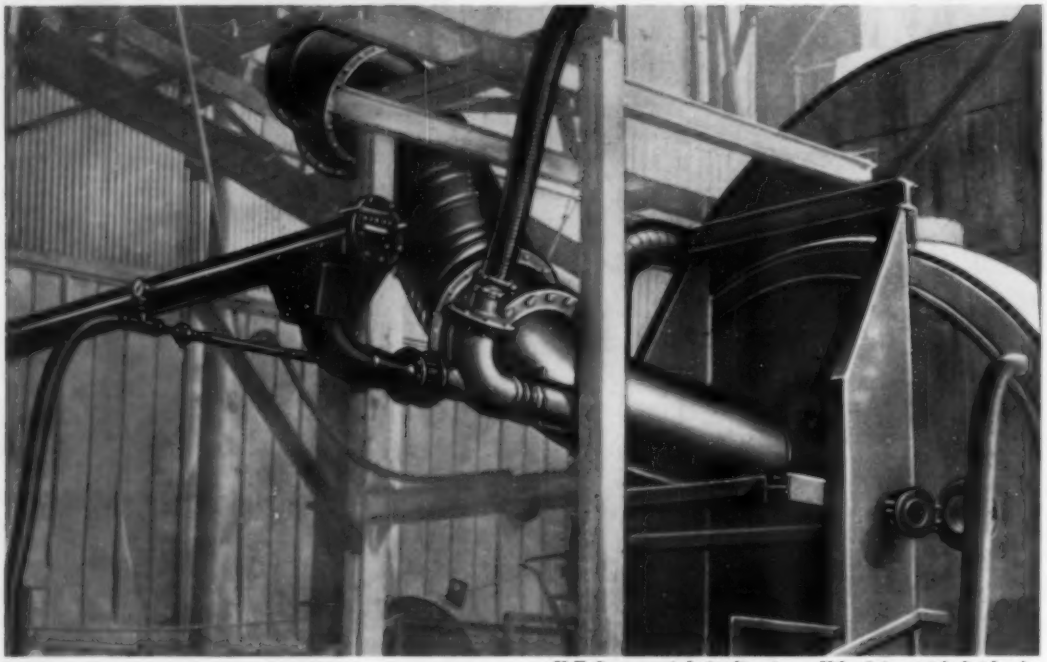

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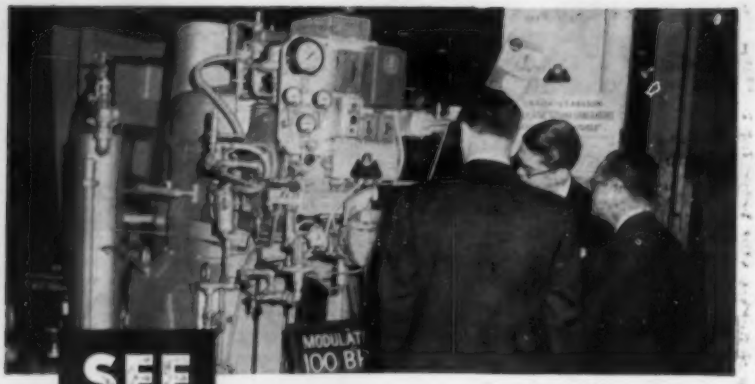

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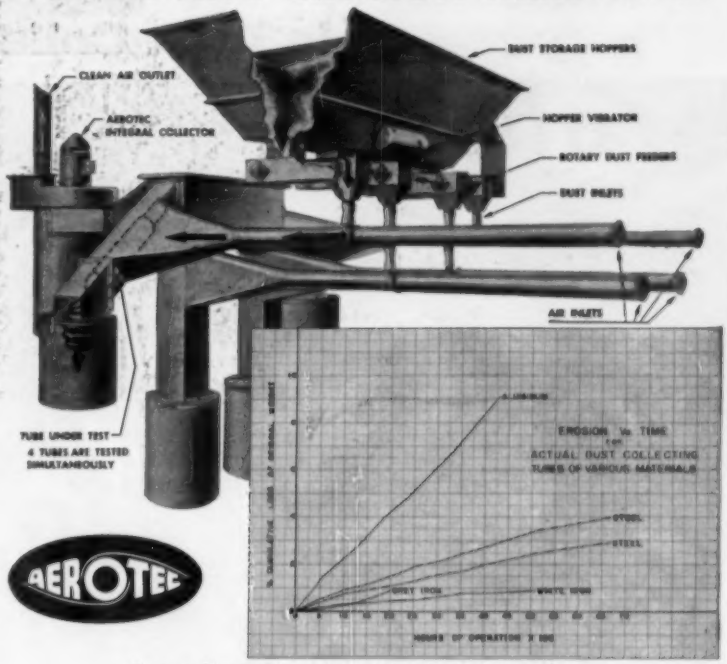
...PROVING EROSION RESISTANCE



AEROTEC

Wear machine developed in our laboratory to test resistance of various metal tubes. Above chart shows loss of weight in tubes of aluminum, steel, grey iron and white iron.

years of research by AEROTEC now assure *longer tube life* for mechanical dust collectors

Dust collector tubes of aluminum, because of the ductility of the metal, were at one time thought to be more erosion resistant than steel. However, *accelerated tests now prove conclusively that of all the basic metals tested, white cast iron tubes assure greatest resistance to abrasion.*

In setting up the test procedure, unusually severe abrasive conditions were simulated—many times more severe than ever encountered in field installations. The most troublesome dust erosion-wise was selected for the test. After 6700 hours of continuous operation, tube wear for various metals produced the curves shown on this page. Note the outstanding performance of the white iron tube. Although in many cases aluminum tubes are proving entirely satisfactory, white iron is now recommended for the majority of new installations.

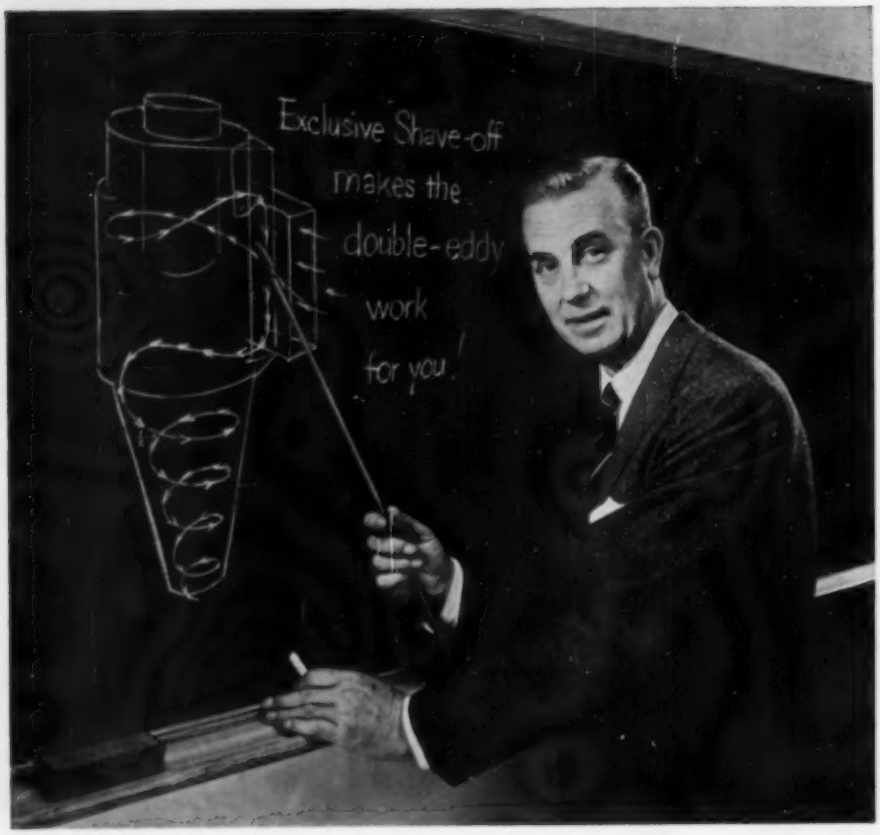
In development for over three years, the new Aerotec 5" white iron tube will assure longer life and continuing high efficiency in your dust collection equipment. Why not call or write today for complete information? Address The Thermix Corporation, Project Engineers for Aerotec.

Project Engineers **THE THERMIX CORPORATION** Greenwich, Conn.
(Offices in 38 principal cities)
Canadian Affiliates: T. C. CHOWN, LTD, 1440 S. Catherine St. W., Montreal, Que.

Manufacturers
THE AEROTEC CORPORATION
Greenwich, Conn.

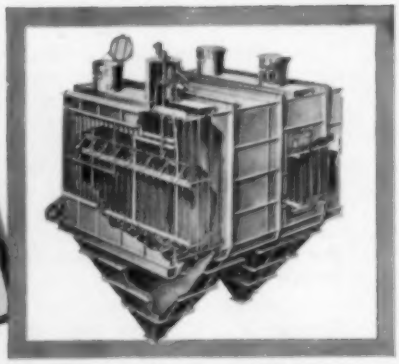
Designers and Manufacturers of Automatic Controls, Valves — Regulating, Relief, and Check Type; Pressure Switches; Gauge, Altitude, Differential and Absolute Types — Float Switches: Top, bottom or side mounted — Single, Dual or Tandem.

How Buell delivers the EXTRA PERCENT in Dust Collection Efficiency

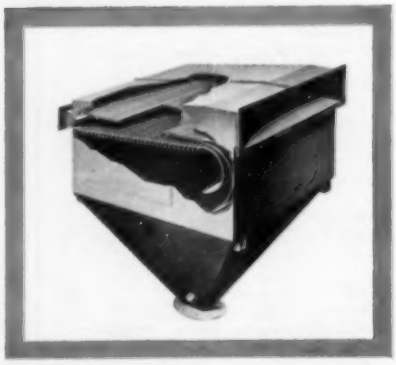


In any cyclone dust collector there is an upward eddy preventing the separation and dropping-out of a percentage of particles. But in Buell Cyclones, the exclusive Buell shave-off design *harnesses* this up-flow—puts it to work! Result: extra efficiency without extra operating cost!

For the complete story behind Buell's *extra efficiency*, write Dept J-70, Buell Engineering Company, 70 Pine Street, New York 5, N. Y.



Buell's Low Resistance Fly Ash Collector combines top efficiency with low draft loss, for either natural or forced draft installations.



SF Electric Precipitator, a Buell exclusive, also delivers *extra efficiency* due to unique Spiralectrodes and continuous cycle rapping.

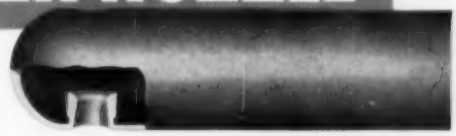
buell

MECHANICAL ELECTRICAL

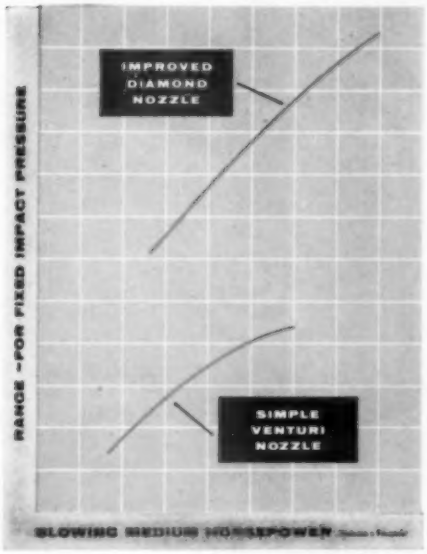
Experts at delivering Extra Efficiency in **DUST COLLECTION SYSTEMS**

GETTING BACK TO FUNDAMENTALS:

Efficient BOILER CLEANING Starts at the BLOWER NOZZLE

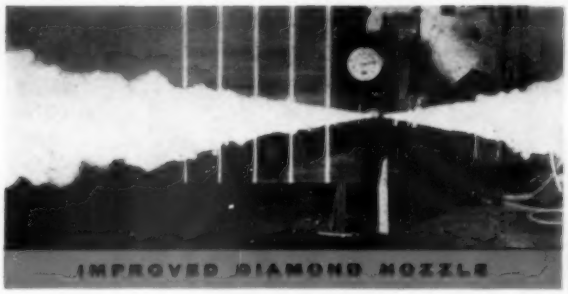


Photograph of section through Diamond "Type A" Nozzle.

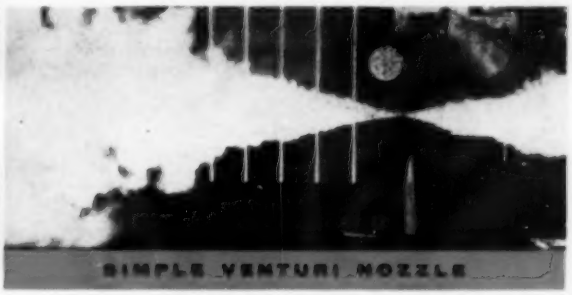


The blower nozzle has the job of converting steam or air pressure into velocity which, in turn, produces impact pressure at the surface to be cleaned. Effective cleaning depends on this impact pressure. A well-designed nozzle will convert much more efficiently . . . doing a better cleaning job with less steam or air.

During the past several years Diamond has conducted intensive research into nozzle design to find the ultimate in efficiency. (More than 50 designs were tested.) It was soon found that nozzle design responds to perfection of detail. Among the details studied were: (1) divergence angle of nozzle, (2) inlet radius as a function of throat diameter, (3) length-diameter ratio of nozzle, (4) area ratio of lance to nozzle throat, and (5) nozzle approach conditions. A product of this research is our new "Type A" Nozzle for Model IK Blowers. The curves at the left show how much more efficient it is than the simple venturi nozzle. The result is improved cleaning at substantially lower energy cost.



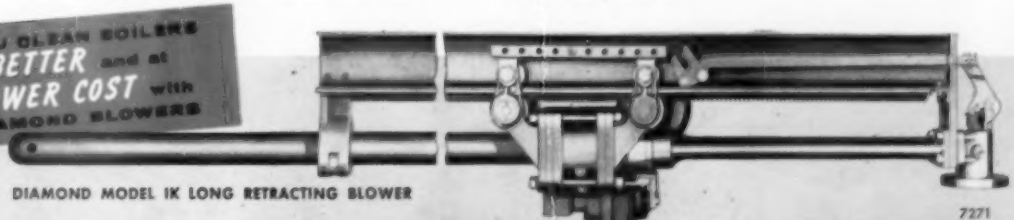
IMPROVED DIAMOND NOZZLE



SIMPLE VENTURI NOZZLE

The two photographs above show the Improved Diamond Nozzle and the simple venturi nozzle under identical test conditions. These tests proved that the effective range of the new Diamond nozzle is substantially greater. Also that at the same range, the impact pressure of the Improved Diamond Nozzle is much higher than for the simple nozzle. For equal cleaning ability, the higher efficiency of the new Diamond nozzle requires a much lower blowing medium pressure.

YOU CLEAN BOILERS *BETTER* and at *LOWER COST* with DIAMOND BLOWERS



DIAMOND MODEL IK LONG RETRACTING BLOWER

7271

DIAMOND POWER SPECIALTY CORP. • Lancaster, Ohio

Diamond Specialty Limited • Windsor, Ontario

tomorrows are planned today

To keep its present homes and farms and industries operating efficiently—and to provide for its *future* homes and farms and industries—the fast-growing Delmarva Peninsula needs a fast-growing amount of power. Supplying that power is the job of Delaware Power & Light Company, which provides for the present while keeping an eye on the future. An example is the recently constructed Edge Moor Power Station, whose three turbo-generators have a net generating capacity of 210,000 kilowatts of electricity. To the Benjamin F. Shaw Company went the contract for fabricating the piping for this large new generating facility. Finished on schedule, the piping shows the results of careful planning and skillful fabrication to meet exacting specifications. When you envision a new piping project, look to the Shaw Company, with its diversified past experience and exceptional present facilities, to help *you* keep an eye on the future.

"It was a real pleasure," says Stuart Cooper, president of Delaware Power & Light Company, "to watch the efficient, methodical, and economical way in which the Shaw Company went about completing its work for the Edge Moor installation. For years, we have heard high praise from others about Shaw's excellent work . . . now we can add to that some praise of our own!"

Benjamin F. **shaw** Company

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